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ENGINEERING AND EQUIPMENT

(FOUO 7/81)



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AERONAUTICAL AND SPACE

UDC 629.78

THERMAL DESIGN OF SPACECRAFT UNITS

Moscow TEPLOVOYE PROYEKTIROVANIYE AGREGATOV LETATEL'NYKH APPARATOV in Russian (signed to press 5 Dec 80) pp 2-8, 174-175

[Annotation, introduction and table of contents from the book "Thermal Design of Spacecraft Units", by Boris Mikhaylovich Pankratov, Izdatel'stvo "Mashinostroyeniye", 1100 copies, 176 pages]

[Text] This book presents modern concepts on the thermal design of spacecraft units (systems for thermal protection of apparatus for reentry, thermostatic control of fuel tanks, power plants etc.). Papers on heat exchange, thermodynamics, aerodynamics, space physics, ballistics, dynamics, nuclear physics etc. were widely used.

The book is intended for engineers who design heat-intensive units for spacecraft.

Introduction

The investigation of thermal modes of units and systems and the selection of their characteristics, taking into account the effect of the environment and the limitations imposed by the parameters of the spacecraft (LA), are a part of the environment in designing heat-intensive designs and the apparatus itself, i.e., thermal design.

When the LA operates for a long time in space, its design and several units and systems are subjected to the effect of the environment and, as a rule, to relatively high thermal loads from external and internal heat sources. The problem of optimal thermal design may be represented conditionally in several stages.

The basic design parameters of the system are determined to the first approximation by taking into account the special features of the trajectory and the duration of the flight. Then, for the selected LA parameters, the motion trajectory of the spacecraft and the optimal characteristics of the units under the effect of the external and internal thermal loads and of the environment are defined more accurately.

Here the problem of the synthesis of the optimal control of the spacecraft may be posed, using the criteria of the minimum weight of one unit or another, the minimum of integral heat flows during the flight, not exceeding the permitted

1

temperature of the unit structures and providing for the optimal thermal mode of their operation. Sometimes a comprehensive functional is used that takes into account, for example, the surface temperature as well as the thermal flows that act on the unit etc.

The presence of radiation zones of solar and cosmic radiations surrounding the earth poses an entire series of problems for the dynamic flight of spacecraft (KLA). The consideration of such problems is related to the necessity of taking into account the radiation dangers to which the crew, the units and the devices aboard the space craft are subjected.

The choice of optimal power engineering in these problems must be made by taking into account the effect of intensive radiation zones. Of interest is the fact that, from the mathematical viewpoint, the nature of these limitations is such that they either eliminate entirely the possibility of using the classical methods of the calculus of variations and the maximum principle, or require their essential modification. Of interest in this case is the consideration of several methods of calculation, for example, dynamic programing etc.

At the first stage of thermal design, it is necessary to a first approximation, but to a sufficient degree of accuracy, to determine the basic power characteristics of the spacecraft and the engine that will be the initial ones for the following analysis and will be made more precise at the following stages.

Essentially the problem is divided into dynamic and weight. Some thermal KLA mode is established under the effect of external(sun radiation, direct or reflected from the planets, its own radiations of planets and the earth, the effect of streams of micrometeorites, protons etc.) and internal (engines, power systems, apparatus etc.) heat sources, by which, for example, may be understood the thermal field, variable in time, in individual design components of the units, systems and the spacecraft as a whole.

The energy from the external heat sources and the energy emitted in the spacecraft from internal sources are converted into thermal radiation. The latter is practically the only method for heat removal in space from heat-loaded KLA units, if the methods based on ejecting matter are not considered.

Due to the small density of the micrometeorites in space, they have little effect on the thermal mode of the spacecraft and should be taken into account only when the KLA passes through a region with a very high meteorite content. However, micrometeorites and other cosmic particles, when striking the skin of the spacecraft, may change the optical properties of the surface of the KLA (due to their high energy) which, in its turn, may have considerable effect on the thermal mode of the spacecraft. In a number of cases, even when flying at great heights, it is necessary to take into account the heating of the sheath of the spacecraft by the impacts of atoms and molecules in the residual atmosphere of the planet. Thus, the temperature of the spacecraft depends to a certain extent on its position in space and its orientation with respect to thermal energy sources, and may vary within fairly wide limits.

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The problem arises of maintaining the thermal modes of preserving fuel components aboard the KLA which may be reduced to optimizing the characteristics of the thermostatic control system, the mass of the fuel compartments or the mass of the entire spacecraft. Here it is necessary to take into account the heating of the fuel components by the external and internal heat sources from which there arise a number of effects related to the heat exchange between the liquid, the wall of the tank and the gas, the boiling, the stratification of the component, steam condensation, supercharge of the diffusion gases etc. (see chapter 5).

To preserve the cryogenic fuel components in the liquid state during the entire flight, it is expedient to use several types of thermostatic control simultaneously ("passive" and "active") or one of the more efficient of them. Many papers are devoted to the problem of various thermostatic control systems. We used the results of these for a thermal design to obtain approximate relationships. By using these relationships to the first approximation, it is possible to determine the area of application of the various thermostatic control systems and the mass relationships between them.

In some cases, thermal currents from engine and power installations affect considerably the thermal mode of the KLA. Here heat transmission is implemented primarily from the jet of the operating engine and, in some cases, becomes the determining factor in the structure of the ionizing radiation of the engine or the power installation. The calculation of the heat exchange systems necessary for the operation of the power installations that affect the thermal mode of the spacecraft as a whole is a complex problem.

Already, at the very early stages of thermal design of the KLA units and systems, there arises the necessity of carrying out a fairly detailed calculation of the design of the thermal mode. Thus, frequently we approach the problem of the theoretical numerical simulation of the thermal mode of the design of the space-craft. Two basic approaches are possible here. The first approach is investigating the thermal mode of individual design components. In this case, as a rule, it is possible with some difficulty to take into account the mutual thermal effect of the design components on each other. The second approach involves an investigation of the thermal mode of the spacecraft by means of a thermal model determined in a certain manner. The model describes the thermal model of the most important LA design components and takes into account their mutual effect on each other (chapter 4).

In the process of mathematical simulation to describe the thermo-physical processes, experimental relationships and methods obtained previously are used, as a rule. The mathematical model prepared for investigating the LA thermal mode makes it possible to investigate it for various conditions of external loading, to take into account the variability of the thermo-physical characteristics of the materials and coatings and, moreover, the changes introduced in the design solution.

Various proposals and methods are used in preparing the mathematical models. Recently, methods based on using the theory of graphs components were introduced in mathematical modeling. These methods may be used successfully also in the automated design of LA and other objects.

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In a number of cases, mathematical simulation makes it possible to investigate thermo-physical processes, whose physical modeling cannot be done under terrestrial conditions. Among such processes are thermo-gravitational convection of low boiling point liquids in LA fuel tanks under weak field conditions and several others.

Mathematical modeling plays an important role in investigating problems of interdependent heat exchange in the proposed complex configuration design because it permits the consideration of the progress of the thermo-physical processes, investigates their mutual effect, solves the problem of optimizing the thermal mode of the design etc.

It should be noted that the LA thermal mode optimization is closely related to the solution of inverse problems of heat exchange in complex shape designs.

Such problems include, for example, those of restoring the termperature profile in mutually related components of the considered design in accordance with the known values of temperatures in individual components. Although these problems are complex even in the formulation plan, it is to be hoped that their solution will be obtained in the very near future.

A completely special area is the part of the thermal design of KLA operating under the effect of intensive ionizing radiation from several power installation of the spacecraft or cruising engines using nuclear fission energy.

Using the solutions of the problems for optimizing the mass and shape of multilayer protection from the reactor radiation, taking into account the evaporated fuel component, it is possible, in general, to solve the comprehensive problem on choosing the optimal parameters of radiational protection, the geometry of the fuel compartment, the mass of the adapter between the KLA booster units and the carrier and evaporated component.

Of considerable interest are problems related to the selection of basic parameters for thermal protection systems for reentry, designed to deliver the crew and scientific equipment to the surface of the planet. The spacecraft upon reentry to the earth's surface is subjected to the strong effect of the environment. In developing the design of such spacecraft a thermal protection system that protects the structure, units, devices, crew etc. from temperature loads plays a considerable role. The investigation of the operation of thermal protection and the choice of its parameters, taking into account the special feature of the environmental effects and limitations imposed by the parameters of the reentering spacecraft, is one of the main parts of the problem of the thermal design of the units and the spacecraft as a whole.

Among the many limitations primarily imposed on the choice of spacecraft parameters in thermal design are the limitations on the choice of the shape. As a rule, the shape of the spacecraft is selected to provide a given lift-drag ratio, stability, ease of control, maximum density of the arrangement, minimum mass of thermal protection and the spacecraft as a whole, its greatest reliability and efficiency, comfort of the crew etc. Here it should be taken into account that the shape of the spacecraft directly affects the type of thermal protection coating used.

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A number of complex problems arise in developing the thermal protection system. One of them is the study of the interaction between the heated gas and the thermal protection materials and the selection of the most efficient of them. The interaction between the heated gas and the thermal protection materials is due to many mutually related processes. The solution of this problem in the general case is based on the solution of a system of differential equations that describe the phenomenon of nonstationary heat-mass transfer in a gas-body system and, at present, represents great difficulties from the mathematical viewpoint. Therefore, in studying such complex phenomena (especially of nonstationary processes), the role of experimental investigations, with the wide application of automatic complexes for gathering and processing data, increases essentially. In many cases, the bases of software for nonstationary thermal experiments are methods for solving inverse problems of heat exchange: the determination of limiting thermal modes, identification of the processes of heat and mass transfer, the restoration of external and internal thermal fields etc.

The thermal design of units, systems and of spacecraft as a whole, is only one of many parts of the general design of the spacecraft. However, this part differs essentially from all the others by the fact that besides the solution of basic problems of LA design, related to mass and ballistic design, it demands from the investigator an extensive analysis of physical phenomena and the application to this analysis of many related sections of science and technology.

Even a short list of basic problems related to thermal design attests to the necessity of applying a wide range of problems in thermal physics, heat-mass exchange, thermodynamics, space physics, ballistics, dynamics, nuclear physics, mathematics etc., needed at the present time to solve the design problems.

This book is one of the first that generalizes the numerous individual papers in the area of thermal design of spacecraft units and, to a certain extent, has the nature of a compendium.

The main purpose of the book is not only to recite the bases of the thermal design of some components of spacecraft and thermal-intensive units, but also to provide the methodology for solving similar problems and provide relatively simple and convenient relationships, useful in determining a number of basic characteristics of spacecraft systems and the calculation of power and thermal parameters at the initial stage of design.

Wherever necessary, concrete numerical values are given in the book. This makes it possible to use the book as a useful reference manual also.

Along with the bases and problems of thermal design of spacecraft, the book presents the concept of the modern level of investigations on the considered questions. The bibliography given in the book is intended basically for further, more extensive study of the individual chapters.

At the request of the author, subchapters 4.3, 4.4 and 4.5 have been written by the senior staff worker, candidate of technical sciences, V. S. Khokhulin, to whom he expresses his sincere gratitude.

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The author is especially grateful to academician V. P. Mishin, who helped greatly in the preparation and writing of this book, as well as to reviewer professor Yu. V. Polezhayev, doctor of technical sciences, for valuable comments and suggestions he made when examining the manuscript.

We are grateful beforehand to all readers who will make critical remarks and suggest improvements to the book.

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POWER SUPPLY AND CONTROL SYSTEMS FOR ELECTRICAL ROCKET ENGINES

Moscow SISTEMY PITANIYA I UPRAVLENIYA ELEKTRICHESKIMI RAKETNYMI DVIGATELYAMI in Russian 1981 (signed to press 30 Jan 81) pp 2-4, 136

[Annotation, foreword and table of contents from the book "Power Supply and Control Systems for Electrical Rocket Engines", by Marks Mikhaylovich Glibitskiy, Izdatel'stvo "Mashinostroyeniye", 930 copies, 136 pages]

[Text] Annotation

This book presents theoretical and engineering problems involved in producing optimized systems for the power supply and control (SPU) of electrical rocket engines (ERD) and spacecraft (KLA). The most developed types of ERD and functional circuits for their power supply and control were considered. Questions of protection for various types of SPU and ERD were elucidated under anomalous and emergency situations.

The book is intended for specialists in the investigation and development of electrical rocket engines.

Foreword

The assimilation and peaceful utilization of space for practical purposes was begun by Soviet cosmonauts on 4 October 1957 and are being developed and improved at a rate unseen in other sectors of science and technology. Low motive power engines -- electric rocket engines (ERD) occupy a special and very important place in the means and devices for developing jet engines for spacecraft (KLA). The ERD have a number of essential differences that place them outside the competition with other types of jet engines. The advantages of the ERD were confirmed by long and successful experiments in space on artificial earth satellites launched in the USSR and the United States.

Broad programs were developed and published recently for further investigations and assimilation of space, including the creation of orbital technological shops -- laboratories, global communications systems satellites, navigation and meteorological satellites etc., in which it is proposed to use ERD. It is planned to use ERD for cruising propulsion engines for interplanetary flights, and to investigate distant space and comets. It is planned to use groups of ERD with a total power counted in hundreds of kilowatts as motive power engines of booster units

for the delivery of sections of solar space electric power plants into geostationary orbits, called upon to supply electric power to industry on the earth by the end of the twentieth century. It is planned to launch scale models of such 150 kw power plants in 1983 [40].

Broad periodical literature and a number of monographs of Soviet and foreign scientists are devoted to the physical bases and principles of ERD operation. These cover theoretical and engineering problems of developing the ERD proper and the primary power sources for the KLA, while the problems of the investigations and developments of ERD power supply and control systems were considered extremely briefly only in a small number of journal articles. This book gives a systematic presentation of the theoretical and practical problems that arise in the development and design of ERD power supply and control systems.

The author is sincerely grateful to professor A. I. Morozov, doctor of technical sciences, whose initiative and constant attention facilitated the appearance of the book, to reviewer professor D. D. Sevruk, doctor of technical sciences, as well as to R. K. Chuyan, doctor of technical sciences, and assistant professor V. Kim for their helpful advice and fruitful discussions of the manuscript that facilitated its improvement.

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NUCLEAR ENERGY

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EXPERIENCE WITH BRINGING ON LINE AND OPERATING THIRD POWER UNIT WITH FAST NEUTRON REACTOR AT BELOYARSKAYA AES

Moscow ELEKTRICHESKIYE STANTSII in Russian No 9, Sep 81 pp 12-17

[Article by V.I. Kupnyy and V.V. Budziyevskiy, engineers, Beloyarskaya AES]

[Text] Power unit No. 3 of the Beloyarskaya AES with electrical capacity of 600 MW has three loops and is designed with a triple loop configuration for heat removal from the reactor; in this case, metallic sodium serves as the coolant for loops I and II, while water (steam) is used as the working material of loop III.

The type BN-600 fast neutron reactor with a thermal capacity of 1,470 MW has an integral layout (tank configuration) for the loop I equipment. The reactor takes the form of a cylindrical tank 12.8 m in diameter and 13.0 m high , which is mounted on roller supports in the reactor shaft. The core is positioned in the reactor tank as well as the three main circulation pumps of loop I, the six process heat exchangers of loops 1-2 (two each for each loop), the internal tank protection with the thermal shields and the neutron channels. The control drives for the control and protection system mechanisms and reloading are positioned on rotating plugs installed in the upper portion of the reactor.

Each of the three loops includes the following: a once-through modular eight section type PGN-200M steam generator with a steam output of 660 t/hr having steam parameters of 505 °C and 140 kgf/cm², a K-200-130 turbine installation with a capacity of 200 MW, a TGV-200M generator, a DSP-800 water feed system with a deaerator and three PE-380-200/185 electrical feed pumps.

The sodium is circulated in loops I and II by single stage centrifugal pumps. The rotor of the pump is mounted in a cantilever bracket fashion on the lower end of the shaft and has a hydrostatic bearing. The utilization of a main circulating pump with an asynchronous rectifier stage makes it possible to continuously vary the r,p,m,'s of the pumps in a range of 250 to 970 r.p.m.

The high parameters of the live steam and the superheated process steam made it possible in the design of the unit to employ standard turbine room equipment with the 200 MW units of thermal electric power stations.

Power unit No. 3 is outfitted with a "Kompleks-Uran" information computer system, which consists of the M-60 data subsystem, a computer subsystem designed around the series produced M-7000 computer and "Orion" data displays.

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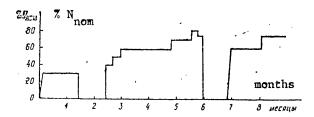


Figure 1. Consolidated graph showing the bringing of the capacity of power unit No. 3 on line at the Beloyarskaya AES.

The "Kompleks-Uran" system calculates and analyzes the technical and economic indicators (TEP) of the operation of the main and auxiliary equipment of the power unit, records the preliminary and postaccident values of the digital and analog parameters and the production process protection which has actuated. Special programs provide for printout of the results.

The operation of power unit No. 3 started April 8, 1980 following the connection of the turbogenerator to the Sverdlovsk power administration power system. Following comprehensive testing, the bringing on line of the unit capacity was started, which was accomplished in the following stages: operation at a reactor power of 30 percent N_{nom} to check the operation of the turbogenerators under load, the adjustment of the water supply mode, operational adjustment of the equipment and power unit system as well as to perform investigative work; operation at a reactor capacity of 40 to 70 percent of N_{nom} to more precisely specify the operational modes of the core, the sodium loops and the major equipment as well as to perform investigative work; operation at a reactor capacity of 80 percent of N_{nom} to more precisely specify equipment operational modes at nominal steam parameters and to perform investigative work.

A consolidated graph of the bringing on line of the capacity of power unit No. 3 is shown in Figure 1. Increasing the reactor power above 80 percent of $N_{\mbox{\scriptsize nom}}$ is possible only after the core becomes steady-state following the execution of three fuel reloadings because of the core physics.

Following comprehensive tests of the production process protection and interlocking (TZB) of the unit and tests of the disconnection of the internal loads of the unit, the reactor was brought up to 0.1 percent of the nominal load. On April 2nd, 1980 following the filling of the steam generators (PG) with feed water and the establishing of circulation through the third loop, the reactor power was increased up to five percent and the steam generators were brought up to steam operating conditions. At this power, the setting of a large number of steam generator safety valves was accomplished. On April 8th, the capacity of the reactor was brought up to 30 percent of N_{nom} , the sodium temperature of loop I at the outlet from the reactor reached 400 °C and the turbogenerators were sequentially connected to the

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power system. To improve safety, the settings of the rate of change in the coolant temperature during start was reduced by a factor of seven below the design value while the coolant parameters and steam were lower than the nominal values but provided safe operating conditions for the steam generators. During the first three days of steam generator operation, the water chemistry conditions in loop TII were established in accordance with the norms for once-through steam generator. In the first stage of bringing the unit capacity on line, the major starting conditions were tested as well as those for shutdown and operation at the steady-state power level. Tests were made of accident modes, including the actuation of the fast reactor accident protection (BAZ), slow reactor accident protection (MAZ) and the disconnection of one loop. In all operating modes, special equipment was used to carefully monitor vibration and tensile and thermal stresses in the components of the major equipment and piping.

The operational setting of the automatic controllers for the production process was accomplished during this same period. The radiation status in the production rooms and the environment was studied. As a result of the first stage of bringing the unit capacity on line, a considerable number of design errors were ascertained in the setting of the transducers for the rate of flow of the feed water and the steam generator steam, something which created considerably difficulties in determining the thermal balance of the unit. The thermal balance was determined from the parameters of loop II, where the electromagnetic flow rate meters were graduated by a correlation technique prior to the power start of the unit. Errors were also discovered in the plan for the setting of the condensate level transducers in the condensors of the turbines, which caused two shutdowns of the turbogenerators (TG) because of overflow of the condensate collectors. The unsuccessful design solutions for the steam supply for internal loads and the steam ejector installation made the operation of the unit considerably more difficult. The large amount of water passed through the fast acting emergency valves for water discharge from the steam generators led to the undetected drying of the steam generators at low power levels. Because of this, a decision was made to dispense with the utilization of these valves and to dry the steam generator through the dump valves at the outlet from the evaporation modules of the steam generators. Considerable reworking was done on the turbogenerator lubrication systems.

From May 14th to June 15th 1980, the unit was shut down to make changes and repairs in the major auxiliary thermomechanical equipment. During this time, the feed water and steam flow rate transducers for the steam generators were rebuilt. At steam generator No. 6, the covers for the water and steam cavities of the evaporation and steam superheating modules were removed to inspect them internally; in this case, no deformations were discovered or corrosion damage and deposits. Measurements were made of the energy liberated in the fuel packets and the sodium flow rates through the packets of the main core were measured. The energy liberated was in line with the design values, and sodium flow rates matched those measured prior to the power start. Tests were performed to specify the hydrodynamic characteristics of loops I and II more precisely and to study the natural circulation mode (YeTs) through loops I and II. Additional safety valves were installed on the steam generators at the live steam headers because of the inadequate carrying capacity of the safety valves called for in the design.

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On June 15th 1980, the reactor was brought up to a power level of 40 percent of N_{nom} and the second stage of bringing the capacity on line was begun. The generator capacity was specified from the thermal balance and was gradually increased up to 50.6 percent of N_{nom} on June 21. The adjustment of the automatic controllers, the automatic water chemistry monitoring system as well as the implementation of programs for production process recording and calculations continued during the operation of the unit. During the process of bringing the capacity on line, with the suspicion of a break of the seal between the loops, four steam superheater modules in steam generators Nos. 4 and 5 were cutoff by means of stop valve fittings and brought out for repair. The work to remove the modules for repair revealed the insufficient capacity of the system for feeding nitrogen into the steam water cavities of the steam generators, something which following the disconnection of a defective module can cause sodium to get into the pipes of loop III. This is promoted by the long duration of the discharge of sodium from loop II, the unreliable operation of the sodium fittings and the routing of the water and steam headers below the modules. In the process of bringing the power up, a degradation was observed in the quality of loop II sodium because of the inadequate capacity of the sodium cleaning system, which did not provide for good retention of the diffusion hydrogen liberated in the sodium, because of which, the cleaning system operates at maximum capacity with the reserve trap filters inserted.

On August 22nd, 1980, the power of the reactor was increased up to 70 percent of N_{nom} , and the temperature of the sodium in loop I at the outlet from the reactor then reached 500 °C, while the electrical capacity reached 380 MW.

The third stage of bringing the power unit on line began on September 16, 1980: the reactor power was increased up to 80 percent of N_{nom} (1,176 MW), and in this case, the temperature of the loop I sodium at the outlet from the reactor reached 510 °C, while the electrical capacity 440 MW.

The unit was shut down on October 3rd, 1980 for scheduled preventive maintenance. During the scheduled preventive maintenance, physical experiments were performed on the reactor to precisely specify the effects of radioactivity, and tests were made to determine the level of residual heat emission and heat losses in loop I. The piping bundles for the high pressure heaters (PVD's) were opened up and flushed with feedwater, after which the high pressure heaters were connected to the steam generator water feed channel. The excitation and the run-out units for the block of turbogenerators were set up and adjusted and the permissible disparities in the rotational speeds of the main circulation pumps of loops I were determined.

After finishing the scheduled preventive maintenance, the block was sequentially run up to the 60%, 70% and 80% of N_{nom} power levels.

Following the connection of the high pressure heaters of the steam turbines, because of the increase in the feed water temperature up to 220 - 230 °C, the iron content in the feed water ahead of the steam generator increased from 5 to 7 $\mu g/kg$ up to 17 - 23 $\mu g/kg$ by virtue of the naturally occurring process of the formation of the protective magnetite film on the internal surfaces of the pipe bundles of the high pressure heaters. The connection of the high pressure heaters increased the electrical capacity of the unit up to 460 MW.

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In the process of bringing the capacity on line, tests were made of the accident and transient modes of the unit, including a test for the run-out of turbogenerator No. 5 with the internal load applied, as well as tests of the skewing of the liberated energy field, studies of the natural circulation conditions for loop 2; a nondesigned circulation mode was tested for loop III with the return of the condensate of the RR-13 expander to the unit deaerators.

Operational experience with power unit No. 3 with the BN-600 reactor confirmed that the actual parameters matched the design values. The major power engineering characteristics of the power unit equipment matched the design values, the unit is easily controlled and the operational modes are stable.

Production process protection systems, interlocking and the automatic regulation systems were incorporated in the operation step by step in accordance with the rise in the power level, providing for safe unit operation in each of the steps.

On April 16th, 1981, the power unit operated in a power generation mode for 240 days, and generated 1,841,522 KWH of electrical power. The nuclear reactor operated for 147 effective days and the maximum fuel depletion reached 3.5 percent of the heavy atoms.

The radiation status is good in the unit: no loss of seal in the fuel rods was detected, the ionizing radiation fluxes correspond to the design values and the emission of radioactive isotopes into the ventilation pipes when the unit is in operation amounts to 1-3 Curie per 24 hours.

During the operation of the unit, systems were prepared for operation which were not included in the operation at the outset of the power start because of the lack of the need for them: the gas purification system, the system for cooling and cleaning the drum of spent packets, the system for cooling and cleaning the water of the holding tank, the equipment of the holding tank and the fuel reloading

The successful mastery of the nominal power level of the first reactor charge was the result of the combined labor of the operating and repair personnel, as well as the personnel of the set-up and research organizations. The success of the collective is the successes of the senior operator of reactor shop No. 2, Yu.D. Krutikov, senior machinist of turbine shop No. 2, Yu.P. Fitsko, electrical shop electrician L.V. Okulov, welder of the thermal automation equipment shop, V.N. Malygin, shift chief of the electrical shop V.I. Batanov and shift chief of the station V.I. Anikin.

Experience with bringing on line and operating power unit No. 3 with the BN-600 reactor made it possible to check and work out the design and production process solutions for the design of even higher capacity power units with sodium cooled fast neutron reactors.

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SELECTION OF SAFETY DEVICES TO COUNTER EXCESSIVE PRESSURE IN PRIMARY AND SECONDARY LOOPS OF NUCLEAR ELECTRIC POWER STATIONS WITH WATER-COOLED REACTORS

Moscow ELEKTRICHESKIYE STANTSII in Russian No 6, Jun 81 pp 11-14

[Article by A.M. Bukrinskiy, candidate of the engineering sciences and E.Ya. Chernikova, engineer, All-Union Institute of Thermal Engineering imeni F.E. Dzerzhinsky]

[Text] The primary and secondary loops of a reactor installation are protected against excessive pressure build-up by safety valves, which are installed on the volume equalizer and the steam generators. The capacity of the safety valves is chosen in accordance with the regulations of the State Committee of the Council of Ministers for the Supervision of Industrial Safety and Mining Inspection [1]. This capacity should be sufficient, so that with the actuation of the valves, the pressure does not exceed the design value by more than 10%.

The safety function assigned to relief valves is an extremely important one. But since it is possible for them to fail to close after actuation, the capacity of relief valves should not be excessively high.

Primary Loop Safety Valves. We shall consider the major possible reasons for a pressure increase in the primary loop. In general, the following three cases are possible:

- --Primary loop overheating due to a mismatch between the heat produced in a reactor and the heat delivery in the steam generators;
- --Steam generation in the volume equalizers by the electric heaters;
- --Pressurization of the primary loop by the pumps during its filling or during a make-up feed.

The latter case is practically nonexistent at present AES's as well as those now being planned, since the capacity of the piston make-up pumps being used, as a rule, is low while centrifugal pumps are chosen from design calculations so that the pressure head developed by them does not lead to the actuation of the safety valves. Of the remaining two cases, the first is the most dangerous.

A mismatch between the heat delivery in a reactor and its removal in the steam generators occurs in the case of disturbances which lead to an excess reactor

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power or to a drop in the turbine load. However, the greatest mismatch between the heat delivery in a reactor and the heat removed in the secondary loop will appear with a complete loss of the capability of removing heat from the secondary loop.

The elimination of the mismatch between the heat delivery and removal in the primary loop is accomplished by means of reducing the energy produced in the reactor, something which is realized by the fast response accident protection for the reactor. The fast response reactor accident protection (AZ1) performs a safety function, and for this reason its reliability should be no less than the reliability of the safety valves. Therefore, at AES's, in contrast to how this is handled in boiler facilities, there is no basis for failing to take into account the action of the reactor accident protection when determining the capacity of the relief valves.

Thus, the emergency reactor protection should be used for the reactor installations as the first stage of protection against excessive pressure, while volume equalizer relief valves should be used for the second stage when the heat delivery to the primary loop is determined by the level of residual energy generation in the reactor.

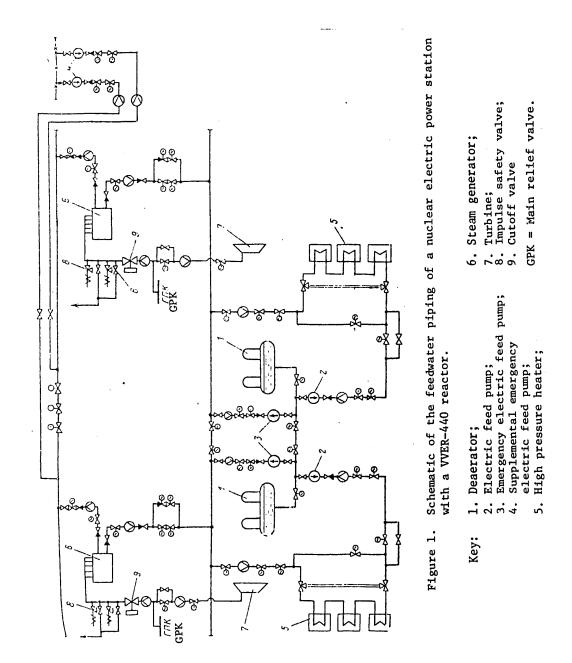
For emergency heat removal from the secondary loop, it is necessary to vent the steam from the steam generators and deliver a make-up feed by means of the emergency feed pumps. Since this system performs an important safety function, it is usually designed in accordance with the requirements of the general principles for the assurance of the safety of nuclear power stations in their design, construction and operation [2].

It is necessary to choose the capacity of relief valves by working from an analysis of accidents with a complete loss of feed water. Such an accident can happen in the case of a break in any feed water pipe. In the worst case, it occurs with a break in the feed water pipe between the check valve and the steam generator, as shown in the schematic of Figure 1. In this case, besides cutting off all of the main feed pumps because of the pressure drop in the main pressure line, there will be a leak from one steam generator. If for any reason there is a total failure of the emergency make-up feed system for the secondary loop, as happened at the Three Mile Island 2 AES [3], the accident will develop under conditions of a total feed water loss.

Such an emergency situation has been analyzed for a power unit with a VVER-400 reactor [440 KW water-moderated, water-cooled power reactor] using the mathematical models described in [3, 4] as well as the "Kontur", "Kompensator" and other programs based on them.

The results of the analysis are shown in Figure 2.

Until the complete evaporation of the water from the secondary loop, no dangerous situation arises since after the actuation of the reactor accident protection, a sufficient removal of heat from the primary loop is assured. However, after the evaporation of the secondary loop water, the cooling of the primary loop ceases and it begins to heat up rapidly. The heating of the primary loop is accompanied



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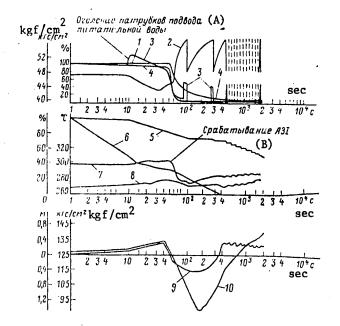


Figure 2. Feed pipe break between the check valve and the steam generator.

Key:

- 1. Water mass rate of flow through the reactor;
- 2. Pressure in the operating steam generators;
- 3. Total steam mass rate of flow;
- 4. Thermal power of the reactor;
- 5. Quantity of water in the operating steam generators;
- 6. Quantity of water in the emergency steam generator;
- 7, 8. Water temperature at the outlet and inlet of the core respectively;
 - 9. Pressure in the volume equalizer;
 - 10. Water level deviation in the volume equalizer from the nominal value;
 - A. Bare exposure of the feedwater branch delivery pipes;
 - B. Actuation of the fast response reactor accident protection.

by a rise in the pressure. This leads to the opening of the relief valves in the volume equalizer. Initially, the steam relief valves actuate and then after the steam cushion is forced out through the relief valves, the hot water runs out. The most dangerous moment begins when the primary coolant starts to boil. At this point in time, the greatest volumetric rate of coolant flow is dumped through the relief valves and this is the governing factor in the selection of the capacity of the volume equalizer relief valves.

Because of the large water reserve in the secondary loop of AES's with VVER-440 reactors, a dangerous situation can arise no earlier than 2.5 hours after the onset

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of the feedwater loss accident. At AES's with the VVER-1000 reactor, the relative water reserve in the secondary loop per unit capacity of the reactor is somewhat less, and for this reason, a dangerous situation with the boiling of the primary loop coolant can begin approximately one hour after the start of a similar accident. The operational personnel have this time available to take steps to restore the feed for the secondary loop. We will note that at the Three Mile Island 2 the emergency feed was restored eight minutes after the start of the accident.

The restoration of the feed is one of the conditions for assuring the operational reliability of AES's, since otherwise the water will boil out of the primary loop, something which in the final analysis can cause damage to the fuel assemblies in the reactor core.

Settings were recommended for the actuation of the reactor accident protection with respect to primary loop pressure and with respect to the water level in the steam generators on the secondary loop side based on an analysis of accident situations for AES's with VVER-440 reactors.

Since relief valves perform an important protective function, the number of them and their capacity should be chosen by working from the requirements of the general principles for assuring AES safety.

The Capacity of Secondary Loop Safety Valves and BRU-A [Quick-Acting Reducers for Atmospheric Steam Venting] Valves. The number and capacity of secondary loop safety valves are likewise selected in accordance with the requirements of [1]. Usually, two valves each with an overall capacity equal to the capacity of the steam generator are installed on each steam generator. If it is assumed that such a capacity is needed to carry out the safety functions assigned to the valves, then the installation of two valves with a capacity of 50 percent each is inadequate to satisfy the unit failure principle. However, this is not so in this case.

Numerous calculations performed at the All-Union Institute of Thermal Engineering imeni F.E. Dzerzhinskiy for the engineering substantiation of the safety of AES's in the process of designing them show that in all cases, the indicated capacity of a single valve is sufficient to protect the secondary loop against excessive pressure. Consequently, the second valve can be treated as a standby for the case of failure of the first valve. This is due to the fact that in secondary loop excessive pressure modes, when the necessity of safety valve operation arises, the capacity of the steam generators does not remain constant, but is substantially reduced.

If the steam generators are not disengaged in the emergency mode, then considering the fact that one backup valve is installed on each of them, we come to the conclusion that protection against excessive pressure in the secondary loop in this instance is assured with a considerable redundancy. From this standpoint, a more dangerous case is steam generator operation with false actuation of the cutoff valve (see the schematic of Figure 1). However, in this case too, a reduction in the temperature head by virtue of the pressure rise in the secondary loop reduces the requisite capacity of the safety valves to such an extent that one valve proves to be sufficient to limit the pressure in accordance with the requirements of [1]. The transient process in this mode is shown in Figure 3.

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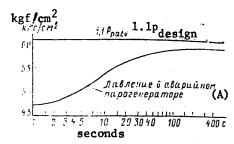


Figure 3. False actuation of the cutoff valve of an AES with a VVER-440 reactor.

Key: A. Pressure in the emergency steam generator.

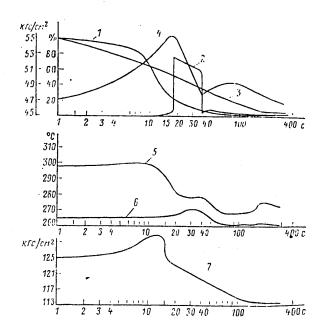


Figure 4. Scramming an AES with a VVER-440 reactor.

- Key: 1. Thermal power of the reactor;
 - 2. Total steam mass rate of flow;
 - 3. Mass rate of flow of water through the reactor;
 - 4. Pressure in the main steam header;
 - 5. Water temperature at the outlet from the core;
 - 6. Water temperature at the inlet to the core;
 - 7. Pressure in the volume equalizer.

In addition to safety valves, fast-acting reducers are installed for dumping the steam into the turbine header and the atmosphere, the BRU-K and BRU-A respectively, to protect against excessive pressure in the secondary loop.

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As numerous calculations have shown, the necessity of the actuation of the relief valves in the secondary loop can arise only when the BRU-K do not work. Such a situation is comparatively rare. Moreover, the probability of safety valve failure can be substantially reduced if their operation in a pulsating mode is prevented, a condition similar to that shown in Figure 2. It follows from this that it is expedient to assign this function specifically to a BRU-A.

As can be seen from the results of calculating total AES shutdown, which are shown in Figure 4, the safety valves close 40 seconds after their actuation following the start of the accident. The residual energy liberation amounts to no more than 5 percent by this time. This value can also be recommended as the requisite minimal capacity of the BRU-A valves. The setting for the opening of the BRU-A can in practice match the setting for the actuation of the relief valves, while the setting for the closing of the BRU-A should be significantly lower than the setting for the closing of the safety valves, something which provides the capability of removing residual heat and cooling through BRU-A following the closure of the safety valves.

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SEISMIC STABILITY EVALUATION OF NUCLEAR POWER STATION ELECTRICAL EQUIPMENT

Moscow ELEKTRICHESKIYE STANTSII in Russian No 6, Jun 81 pp 8-11

[Article by V.V. Piskarev, candidate of the engineering sciences, and D.K. Ponomarev, engineer, Scientific Research Department of the All-Union Planning, Prospecting and Scientific Research Institute imeni S.Ya. Zhuk]

[Text] One of the major requirements for the reliable operation of nuclear electric power stations being built in seismically active regions is the preservation of the operability of the category I electrical equipment (ETO) during and after an earthquake. The level of seismic activity can reach such values that taking into account the dynamic characteristics of the support structures for the electrical equipment, there is the probability of failure of individual constituent components and instruments. Methods exist for the evaluation of the seismic stability of electrical equipment, which consist in vibration load testing of the equipment using vibration test stands. The wide scale dissemination of these techniques is difficult because of the use of special vibration test platforms, the necessity of shipping the equipment to the test site and the simulation of the equipment operating conditions.

A method is described in this paper which makes it possible to operationally evaluate the seismic stability of electrical equipment directly in an AES. The technique permits the determination of equipment operability under seismic loads, specified in the form of accelerometer graphs of earthquakes.

Both in domestic practice and abroad [1, 2], seismic stability testing of electrical equipment, as a rule, reduces to the following tests:

1. Panels, control boards and stands which are included in the electrical equipment complement are mounted on a base made of steel channels which are rigidly fastened directly to a VPZK-100 vibration test platform. The platform is coupled to a hydraulic drive, which generates harmonic vibrations in a frequency range of 1 to 50 Hz. The equipment being tested is connected to electrical circuits which simulate operational conditions, and its operability is registered during this.

The dynamic (vibration) load conditions are specified by working from the nature of the design accelerometer recordings of an earthquake. In the case of failures in the operation of the electrical circuits, the stiffness of the support structure is increased and the tests are repeated. As experience has shown, the costs

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of imparting additional rigidity to the electrical equipment being tested is significantly less than the cost of engineering design work related to the replacement of component parts or re-equipping.

2. Individual types of component parts (relays, contactors, instruments) which are incorporated in a panel under test are mounted on a special vibration test stand, for example, the VEDS-400 using the same method as when mounted in the panel. Then the product being tested is connected to the electrical circuits and its operating parameters are recorded. The vibration test stand sets accelerations in a range of 2 to 50 Hz with a step of 1 Hz, at which the component fails. As a result, the amplitude-frequency limit of operability of the given product is determined. The panel in which the previously tested components are installed is rigidly secured to a VPZK-100 test platform. The vibrational platform sets the oscillatory load conditions in accordance with the character of the design earthquake acceleration graphs. The accelerations are recorded at the points where the components are fastened. The seismic stability of the panel is evaluated by comparing the operability limit of the product and the maximum acceleration recorded in the region where it is secured during tests of the panel itself.

Tests of electrical equipment using the procedures given here are undoubtedly an essential part of the work which makes it possible to evaluate equipment seismic stability, and will serve as the basis for making the necessary recommendations. A drawback to the indicated techniques is the fact that at each point in time, a single frequency sinusoid acts on the product being tested rather than a spectrum of frequencies, as occurs under actual conditions.

The fastening of panels in an AES is quite different from the fastenings on test stands. This in turn leads to a variation in the dynamic properties of the support structures of the electrical equipment, and is reflected in its seismic stability.

In the final analysis, a comprehensive test of the electrical equipment installed in the assigned locations in an AES building is required, and where necessary, additional steps must be taken to assure its seismic stability.

To resolve the problem posed here, work was done to design a comprehensive test procedure for equipment under AES conditions. This method includes both the experimental and computational portions.

The tests of electrical equipment for seismic stability under AES conditions provide for the performance of the following work:

--The testing of relays, contactors, instruments and other products included in the complement of electrical equipment under harmonic loads for the purpose of determining their amplitude-frequency limit of operability. Thus, for the RP-23 relay, the curve of the operability of this product was obtained as a function of the amplitude loading and frequency (Figure 1). The failure curve was plotted starting at 8 Hz, since the technical capabilities of the VDES-400 do not allow for setting adequate accelerations in the range up to 8 Hz. However, under those accelerations which were obtained using the vibration stand in this range, the relay maintained its operability. As can be seen from the graph of Figure 1, exceeding a dynamic mode of 4 m/sec2 leads to failure of the RP-23 relay at a

frequency of 39 Hz. Working from this, the permissible loads on this relay for its reliable functioning during a seismic event should not exceed 4 m/sec^2 throughout the entire frequency range;

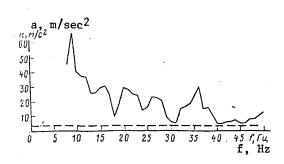


Figure 1. Operability curve of the RP-23 relay.

Key: Solid line is the failure curve;

Dashed line is the maximum acceleration amplitude at which the relay maintains its operability.

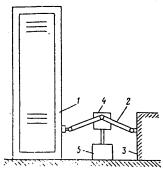


Figure 2. The device for dynamic tests of structures.

Key: 1. Structure being tested;

Two-link mechanism;

3. Support; 4. Ring;

5. Drive

--The recording of the load applied to the lower part of the product being tested, and the response to this dynamic load in the regions of the fastenings of the component products;

--The calculations, which consist of the determination of the values of the recorded loads on reactions and the determination of the transfer functions $W(j\omega)$ of the system formed by the base of the support structure being tested and the region of the installation of the component product secured to this support structure. This makes it possible to determine the maximum acceleration of oscillatory motion of the product with a load specified in the form of a transformed acceleration trace of the design earthquake, taking into account the dynamic characteristics of the AES building;

--The evaluation of the seismic stability of the equipment by means of comparing the amplitude-frequency limit of operability of the component products and the maximum accelerations of their oscillations on the support structures of the electrical equipment.

A special device was developed for the capability of specifying the shock dynamic load in the base of the support structure of electrical equipment. The device [3] takes the form of a two-link mechanism, the lengths of which are coupled together in a hinged fashion, where the mechanism is positioned between the lower part of the support structure of the electrical equipment and a support; in this case, central hinge is tied to a ring which is coupled to the drive. The device for dynamic tests of structures is shown schematically in Figure 2.

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The device operates as follows: the requisite aperture angle of the links of the device is set and the coupling ring is moved by means of the drive; in this case, the center hinge moves from the upper position to a position of unstable equilibrium. As a result of the rapid removal of the force produced by the device in the lower portion of the product, there is a jump-like change in the acceleration, which is determined by the amount of the initial displacement and the rigidity of the structure being tested.

The amount of force produced in the lower portion of the structure being tested depends on the aperture angle of the linkage of the device, for which a provision is made to adjust it.

The impact of an earthquake on the equipment housed in an AES depends not only the earthquake parameters, but also on the dynamic properties of the building.

We did not determine the acceleration of the floors, on which the electrical equipment is placed, due to the action of the design acceleration graphs for earthquakes, since this was specified beforehand.

The initial parameters for the determination of electrical equipment seismic stability, using the LETO program, which was designed for this purpose, are: $x^{\mu}(t) \ [x^{i}(t)] \ is \ the \ impulse \ action \ at \ the \ base \ of \ the \ support \ structure \ for \ the electrical equipment; \ y^{\mu}(t) \ [y^{i}(t)] \ is \ the \ reaction \ at \ the \ point \ where \ the \ component \ product \ is \ located \ due \ to \ the \ action \ of \ the \ pulsed \ load; \ x^{A}(t) \ is \ the \ acceleration \ graph \ of \ the \ design \ earthquake \ at \ the \ installation \ level \ marker \ for \ the \ equipment \ being \ tested.$

By means of the LETO program and the output data needed for seismic stability evaluation of each equipment unit, provisions are made for the output of the results of the response of electrical equipment support structures at the points where the component products are fastened, in the form of a time function $y^p(t)$. The seismic stability of the electrical equipment is evaluated on the basis of a comparison of the amplitude-frequency limit of the operability of each component product incorporated in the equipment unit being tested, and the maximum amplitude of yP(t).

Thus, the program for calculating the seismic stability of electrical equipment includes the following steps. The two functions $x^i(t)$ and $y^i(t)$ are specified, each of which is other than zero only in a certain range $0 \le t \le t_k^x$; $0 \le t \le t_k^y$.

The Laplace transformation of the indicated functions yields $X^i(\omega,c)$, $Y^i(\omega,c)$ and the absolute values and arguments of the functions respectively: $\left|X^i(\omega,c)\right|$, $\phi^i_X(\omega,c)$; $\left|Y^i(\omega,c)\right|$, $\phi^i_Y(\omega,c)$. Then the following quantities are determined:

$$R\left(\omega,\ c\right) = \frac{\left|X^{n}\left(\omega,\ c\right)\right|}{\left|y^{n}\left(\omega,\ c\right)\right|},\ F\left(\omega,\ c\right) = \varphi^{n}_{\ x}\left(\omega,\ c\right) - \varphi^{n}_{\ y}\left(\omega,\ c\right).$$

The Laplace transform of the function $x^{a}(t)$ is realized:

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$$X^{a}(\omega, c) = \int_{0}^{t} e^{(c-i\omega)t} x^{a}(t) dt,$$

And the absolute value and argument of the function $x^a(t)$ are found:

$$|X^{a}(\omega, c)|, \varphi^{a}(\omega, c)$$

Then the following functions are found:

$$K(\omega, c) = R(\omega, c) | X^{a}(\omega, c) |;$$

 $A = \{ C(\omega, c) = F(\omega, c) + \varphi^{a}_{x}(\omega, c) ; \}$

And the complex-valued function:

$$W'(\omega, c) = |K(\omega, c)| e^{i \arg L(\omega, c)}$$
.

By performing the inverse Laplace transform of the function $W(\omega,c)$, we obtain the desired function $y^p(t)$ of the acceleration of the component product motion due to the dynamic impact of $x^a(t)$, specified at the base of the electrical equipment support structure.

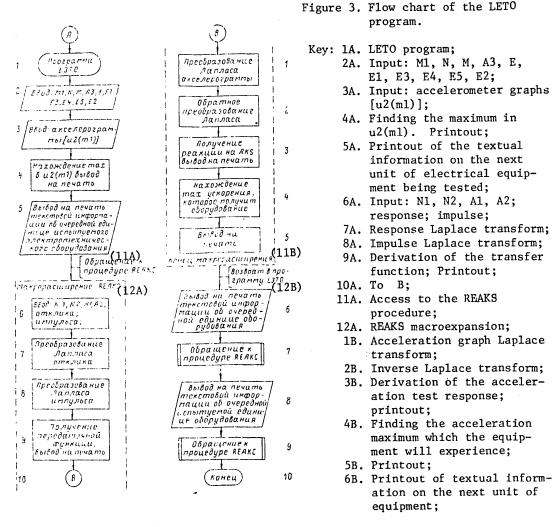
The time needed to compute a single reaction on YeS 10-40 computer is 5 to 10 minutes. A flow-chart of the LETO program is depicted in Figure 3.

Work was done on several individual kinds of equipment panels (KIPiA [control and measurement instrumentation and automation equipment], DGS [expansion unknown]) to determine their transfer functions. The transfer functions were determined using vibraton test platforms in one case and a comprehensive technique in another.

The studies showed that with the same fastening for each product, the transfer functions correspond to each other in a frequency range of 1 to 30 Hz. The results obtained made it possible to recommend the comprehensive technique for the estimation of the seismic stability of equipment.

So this technique is utilized in evaluating the seismic stability of the electrical equipment of the "Kozloduy" AES in the Bulgarian Peoples Republic, where calculations and full-scale tests were run on 136 units of equipment, in which the following were included: BShchU [expanswon unknown], SUZ [control and protection system, RTZO [expansion unknown] and the KRU-0.4 [0.4 KV cubicle switchgear]. We shall consider the procedure for performing the appropriate work.

The RTZO panel is included in the system for the protection and switching of the electric motors of the gate valve fittings and is located at the +9.6 m



7B. Access to the REAKS procedure; 8B. Printout of textual information on the next unit of equipment being tested; 9B. Access to the REAKS procedure; 10B. End; 11B. End of the macroexpnasion; 12B. Return to the LETO program.

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height marker. One of the weakest elements of this panel from the viewpoint of vibrational strength is the RP-23 relay. The amplitude-frequency limit of operability of this relay is shown in Figure 1. A failure in its operation was taken to be any short-term openings of its contacts. It can be seen from the graph that for a frequency of 39 Hz at accelerations of more than 4 m/sec², the relay loses its operability.

Under natural full-scale conditions, i.e., taking into account the specific features of the fastening of the Sh4NM33 panel, a dynamic load was produced in the lower portion by the device described here. In this case, the accelerations were recorded on type UF-67 recording paper using piezoelectric sensors, a SM-231 amplifier and a K-115 bifilar oscillograph. The maximum acceleration of the Sh4NM33 panel in the region of the RP-23 relay was obtained as a result of the calculations; this amounted to $10.0 \, \text{m/sec}^2$, for the case of exposure to the specified earthquake accelerometer graph.

A comparison of the amplitude-frequency limit of operability of the RP-23 relay and the maximum value of its oscillations for the case of the design earth-quake demonstrated the necessity of increasing the stiffness of the support structure of the 4NM33 panel. Repeated tests which were performed after increasing the stiffness of the support structure showed a significant improvement in the seismic stability of this panel and the capability of its operation under the conditions of the "Kozloduy" AES.

Conclusions

- 1. The seismic stability of AES electrical equipment is evaluated by a comprehensive technique, taking into account the specific features of its fastening under AES conditions.
- 2. The comprehensive technique enables on-the-spot evaluation of the seismic stability of AES equipment under natural full-scale conditions and can be used in the acceptance testing of equipment for operation following its installation in a station.
- 3. The range of applications of the comprehensive seismic stability evaluation technique is not limited to studying just electrical equipment, but also with a particular approach, can be extended to the evaluation of the seismic stability of several kinds of production process equipment: the primary loops, valve fittings, piping systems.

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CSO: 8144/1794-A

UDC[621.311.25:621.039]:621.322-81:621.313.126.001.4

BRUSHLESS EXCITERS OF 500-MW TURBOGENERATORS IN ATOMIC POWER STATIONS

Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 81 pp 16-18

[Article by engineers V. D. Vekshin, I. D. Dronov, N. A. Isakov and I. Ya. Cheremisov and candidates of technical sciences V. S. Kil'dishev and Yu. A. Kozlov, Scientific Research Institute of the Elektrotyazhmash plant at the Novovoronezhskaya AES]

[Text] In the past decade, the Scientific Research Institute and the Elektrotyazhmash plant developed, manufactured and installed brushless exciters for 200 and 300-MW turbogenerators with a 3,000 min⁻¹ frequency of rotation and for 500-MW turbogenerators with a 1,500 min⁻¹ frequency of rotation at a number of thermal and electric power stations.

A distinguishing characteristic of these exciters is the application of a rotating multiphase AC generator with trapezoidal-waveform e.m.f. in the armature-winding phase as a power source. This is achieved by means of a uniform air gap between the armature and the inductor; the presence of two exciter windings on the inductor whose electrical axes are perpendicular; the armature winding phases' arrangement in coils having identical positions under the poles; and by means of their connection in a star [1].

The trapezoidal waveform of the e.m.f. in the armature-winding phase makes it impossible to present a clearly defined current distribution with respect to the maximum e.m.f. As a result, the simultaneous operation of several rectifiers and armature-winding phases is realized [2], which undoubtedly is a factor in improving the utilization of the rectifier and the resistive materials in the multiphase AC generator.

These principles and features were realized in the brushless exciters for 200 and 300-MW turbogenerators. Studies of these exciters have shown, however, that with an incomplete number of rectifiers in the rotating rectifier assembly, for example, if one accidentally becomes unserviceable, the overload on the individual rectifiers remaining in operation is approximately 80 percent. This made it necessary to impose restrictions on the operating conditions of the exciters.

In order to insure the serviceability of the exciter when operating with an incomplete number of rectifiers, an armature-winding arrangement using five parallel paths in phase was employed during the development of a brushless exciter for

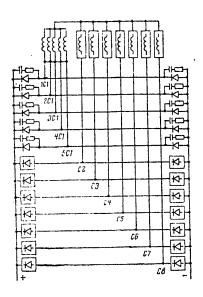


Fig. 1. Electric circuit for connecting the armature winding and the rotating rectifier assembly

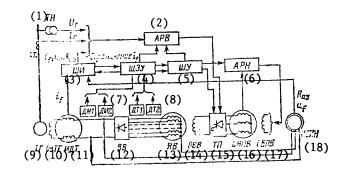


Fig. 2. Block diagram of the brushless exciter system

- 1. Voltage transformer
- 2. Automatic excitation regulator
- 3. Measurement cabinet
- 4. Protection-unit panel
- 5. Control cabinet
- 6. Automatic voltage regulator
- 7. Magnetic sensors
- 8. Current sensors
- 9. Turbogenerator

- 10. Turbogenerator exciter winding
- 11. Induction current sensor
- 12. Rotating rectifier assembly
- 13. Armature winding
- 14. Exciter field winding
- 15. Thyristor converter
- 16. Pilot exciter armature winding
- 17. Pilot exciter field winding
- 18. Insulation-resistance and voltage meter

500-MW turbogenerators with a 1,500 min⁻¹ frequency of rotation. The electrical connection of the parallel phase paths is on the side of the alternating current, while the parallel connection of the rectifiers is on the arms of the rotating rectifier assembly (fig. l). This, together with the retention of the basic principles, was a step forward in the direction of improving the operational characteristics of brushless exciters.

Two TGV-500-4 turbogenerators with an output of 500 MW at a frequency of 1,500 min⁻¹ were installed at the Novovoronezhskaya AES. They are fitted with BTV-500-4 multiphase diode-type brushless exciters, the basic data for which are cited below:

	Valu	18
	Nominal	<u> High-speed</u>
Output, kW	2340	7740
Voltage, V	485	882
Current, A	4820	8760
Frequency of rotation, min ⁻¹	1500	1500
Frequency of e.m.f. in armature, Hz	125	125
Duration of operation, s	Long-term	20

Figure 2 shows the block diagram for the brushless system of the exciter on the TGV-500-4 turbogenerator at the Novovoronezhskaya AES.

We will examine the purpose of the principal elements of the diagram.

The turbogenerator's exciter winding is supplied from the rotating unregulated rectifier unit assembled using a bridge arrangement. The rotating rectifier unit is supplied from the armature winding of a multiphase AC-current generator. The exciter's field winding is supplied from a thyristor transformer connected to the pilot exciter—a high-frequency induction generator, the current in which is maintained at a given level by an internal automatic voltage regulator through the effect of the pilot exciter's field winding.

Monitoring of the turbogenerator's excitation current i_f is accomplished in a contactless method with the help of an induction-current sensor [3].

Control of the excitation voltage U_f and the insulation resistance R_i of the turbogenerator's rotor is accomplished with a contactless insulation-resistance and voltage meter [4], which, in addition to fulfilling its basic functions, signals when there is damage to the winding insulation at a single point and provides for circuit protection from faults to the turbine casing at two points.

The given measurements of the values for i_f , U_f and R_i arrive at the panel instruments of the metering cabinet.

To insure continuous monitoring of the status of the rectifiers in the rotating rectifier assembly, the exciter is equipped with a system of magnetic and current sensors which make it possible to obtain continuous information about the rectifier's

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operation at the protection-unit panel. This protects the rectifier as well as limits the exciter current i_f when there is an incomplete number of rectifiers in the assembly.

The excitation of the brushless exciter is controlled by an automatic excitation regulator which receives information about the turbogenerator's output parameters—the voltage \mathcal{U}_G and the current \mathcal{I}_G with the help of voltage and current transformers. Information about the parameters of the exciter is obtained with the help of the meter cabinet and the protection—unit panel. The automatic exciter regulator, acting upon the thyristor converter, controls the excitation of the exciter and the turbogenerator within the required limits.

When the automatic exciter regulator malfunctions, the control over the excitation is accomplished manually by using the apparatus in the control cabinet.

We will examine briefly the basic design features of the exciter.

The exciter is constructed on two pedestal-type sliding bearings. The multiphase AC generator, rotating rectifier, pilot exciter and the unit for contactless measurement and control of the exciter's parameters are located in a common noise-suppression housing whose design insures the circulation of the necessary volume of cooling air in order to draw off losses emanating from the exciter's resistive portions.

The multiphase generator's armature is assembled from sheets of hot-rolled electrical steel with an enhanced silicon content. In the grooves on the armature is bedded the eight-phase lap winding with diametrical pitch and five parallel branches. The winding leads are connected to the rectifier through a system of terminal buses. In order to reduce additional losses in the winding, an end transposition is carried out in the coils of the winding in the direction opposite the leads. The head portions of the armature are protected from the effects of centrifugal force by binding rings made from nonmagnetic material.

The inductor of the multiphase generator is assembled from sheets of hot-rolled electrical steel. Two distributed exciter windings consisting of multiturn sections of the same dimensions are set in grooves in the inductor. In order to reduce the excitation power and decrease the level of additional losses on the surface of the armature, the grooves on the inductor are set with keys made from a magnetic dielectric material.

The rotating rectifier is assembled on a supporting wheel which bears on a centering ring. The wheel is hot-pressed onto the exciter's shaft. To the centering ring are affixed the cooling elements—radiators which insure reliable elimination of losses which emanate from the rectifiers.

The radiators are made from an aluminum alloy and have a distributed cooling surface. Flange-type silicon rectifiers designed for a maximum current of 500 A and a reiterative voltage of 2,000 V are attached to the radiators. They are mounted in such a way that the plane of the rectifier's p-n structure is perpendicular to the radius of rotation. The total number of rectifiers on the rotating rectifier assembly is 80. In order to protect them from switching surges, an R-C network, designed as a separate unit, is mounted on the end of the radiator parallel to each rectifier

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The rectified current is passed through a system of leads to the DC lead located on the exciter shaft. It is then passed through an electromechanical coupling to the lead of the turbogenerator rotor.

Below are cited the results of tests performed on the BTV-500-4 brushless exciter mounted in a plant test unit.

Current distribution betweeen the rectifiers on the rotating rectifier assembly was studied under short-circuit operation with nominal current. This was accomplished with the aid of a measuring current-collector and shunts installed instead of fuses. In order to insure serviceability of the exciter under conditions in which there were an incomplete number of phases, provisions were made for the installation of five rectifiers in parallel in each arm of the rectifier assembly. These five rectifiers which were selected had a voltage drop of ±0.01 V accuracy. The results of the investigation showed that the difference in the currents in parallel-connected rectifiers was -8.3 to 6.7 percent with the complete number of rectifiers, and did not exceed ±10 percent of the mean value with one rectifier disconnected.

Under-load conditions were examined with the rectifier unit's ohmic-resistance equal to that of the turbogenerator's rotor. In this case, the rectifier insures the smooth regulation of the load current from 0 to nominal current and higher, up to values corresponding to the high-speed values.

When the rectifier unit was operating under resistive load, the efficiency was determined using the method of individual losses. The value for the efficiency was 89.3 percent. The efficiency obtained differs from the calculated efficiency, equal to 90 percent, within the limits allowed by State Standard 183-74.

The determination of the rectifier unit's high-speed response characteristics was accomplished while running it under a resistive load in a two-stage high-speed test. In this case, additional resistance in the rectifier unit's winding circuit was absent. The rate of rise under high-speed operation was $7.72~\rm s^{-1}$. The rate of rise when operating on the turbogenerator rotor and in the presence of additional resistance from the exciter's winding circuit should be expected to be not less than $18.6~\rm s^{-1}$.

In order to determine the elevated temperature in the active portions of the auxiliary generator and pilot exciter and in the elements of the rotating rectifier assembly, temperature indicators—copper—constantan thermocouples—were installed during the manufacturing process. The temperature of the cooling air was measured using resistance thermometers installed in the hot and cold—air chambers in the exciter housing.

The thermal state of the exciter was studied under set conditions for no-load, short-circuit, under-load and high-speed resistive operation. Below are cited the results from the measurement of the temperature excesses in the rectifier elements and their maximum allowable values. Measurements were carried out with a nominal load on the rectifier unit and with a complete number of rectifiers in the arm as well as with the disconnection of one and two rectifiers in the arm.

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	Temperature excess, °C		
	Measured	<u>Allowable</u>	
<pre>Inductor: Portion of the winding: Grooved Core</pre>	63 54	115 115	
Armature: Portion of the winding: Grooved Head Core Binding ring Clamping flange	67.6 99.2 63.4 80 20	115 115 115 115 115	
Base of rectifier in assembly: With complete number of rectifiers With one disconnected rectifier With two disconnected rectifiers	32.2 39 39.4	60 60 60	
Pilot exciter: Grooved portion of armature winding Armature core Exciter winding	54 55 1.00	115 115 115	

During the course of two hours of testing in the two-stage high-speed mode, additional heating in the amount of 11.8 °C was found in the rectifier base.

The results of the thermal analysis of the exciter cited indicated that the temperature excesses in the exciter's active portions were well within limits. This testifies to the correctness of the choice of the electromagnetic-load level and the adoption of the basic design solutions.

The results of investigation and preliminary analysis of the operation of the BTV-500-4 brushless exciters at the Novovoronezhskaya AES point out their high degree of serviceability and confirm the necessity of the further development and introduction of brushless exciters at our country's electric power stations.

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UDC 621.039.566:621.039.517

OPTIMIZATION OF VVER-440 REACTOR ENERGY DISTRIBUTION

Moscow ATOMNAYA ENERGIYA in Russian Vol 49, No 4,0ct 80 pp 254-255

[Article by V. V. Pobedin and V. D. Simonov in "Letters to the Editor"]

[Text] A method of minimizing the nonuniformity of reactor energy distribution [1] was employed for the optimization of seven successive VVER-440 fuel charges. The composition of the first charge and the arrangement elements of control were in accordance with the information given in [2]. At the conclusion of each successive run the most burnt-up fuel assemblies were removed and the reactor was replenished with fresh fuel enriched 2.4% and 3.6%.

Table 1. Burn-up of Fuel Charges

•			Rı	ın Number	<u>:</u>		
Characteristics	1	2	3	4	5	6	7
Run, effective days Average accumulation of poison in unloaded	349 349	287 287	299 301	29 <u>6</u> 292	299 287	296 299	299 285
<pre>fuel, kg/t U: 2.4% enrichment</pre>	$\frac{14.39}{11.12}$	$\frac{22.68}{22.53}$	22.32 22.76	25.05 28.25	23.05 26.84 31.85	24.47 28.29 31.79	24.46 26.71 31.87
3.6% enrichment Average accumulation of poison in the reactor	-	-	31.77 31.43	31.70 30.49	30.20	30.39	30.18
<pre>fue1, kg/t U: 2.4% enrichment</pre>	13.26 13.23	$\frac{12.76}{13.24}$	15.18 15.76	13.50 15.28	14.25 15.51	13.65 15.40	14.18 15.47
3.6% enrichment	$\frac{10.18}{10.33}$	$\frac{15.60}{15.64}$	$\frac{15.33}{14.74}$	$\frac{15.62}{14.59}$	$\frac{15.52}{14.22}$	$\frac{15.93}{14.68}$	$\frac{15.51}{14.62}$

Note: Here and in Table 2: 1) numerator--optimized charges, denominator--formed according to system of operation in [5]; 2) all fuel enriched 1.6% unloaded after first run; 3) make-up fuel constituted: 36 and 84 assemblies after odd-numbered runs, 31 and 84 after even-numbered at 2.4% and 3.6% enrichment, respectively.

The optimum fuel arrangements, corresponding the minimum of the coefficient of non-uniformity of radial energy distribution $K_{\rm r}$, were determined for the start-up of each run with maintenance of 30° core symmetry. The working group of control assemblies was, in this case, in the 175-cm position since, for the active zones under consideration here, the least nonuniformity of energy distribution within the limits of movement of the control and safety rod assemblies correlates with that starting position, according to calculations [3].

Table 2. Coefficient of Nonuniformity of Energy Distribution

			Rur	n Number			_
Characteristics	_1_	2	3	4	5	6	7
Coefficient of non- uniformity K _r : at start of run	1.238 1.311 1.270	1.236 1.281 1.25	1.249 1.318 1.265	1.245 1.314 1.256	1.211 1.298 1.283	1.255 1.317 1.261	1.256 1.293 1.260
maximum	$\frac{1.270}{1.311}$	1.289	$\frac{1.325}{1.325}$	1.314	1.307	1.319	1.301
Time to maximum K_r , effective days	<u>40</u> 0	287 20	299 20	<u>296</u> 0	<u>299</u> 20	<u>20</u> 20	<u>20</u> 20
Coefficient of non- uniformity K _v : at start of run maximum	1.867 1.992 1.905 1.992	1.663 1.663 1.725	1.695 1.682 1.695 1.682	1.752 1.815 1.793 1.815	1.626 1.699 1.646 1.721	1.706 1.820 1.706 1.844	1.649 1.690 1.649 1.723
Time to maximum K_V , effective days	<u>20</u>	<u>0</u> 287	<u>0</u>	<u>296</u> 0	<u>299</u> 287	<u>0</u> 299	0 285

Data obtained by means of the three-dimensional program BIPR [possible expansion-bystrodeystvuyushchaya ispytatel naya programma reaktorov=high-speed reactor test program] [4] concerning the depth of burn-up of the fuel and the length of the successive reactor runs with minimized $\rm K_r$ are presented in Table 1, and the radial and volumetric coefficients of nonuniformity of energy distribution of the reactor are presented in Table 2. The radial coefficient of nonuniformity at the start of each of the seven reactor runs turns out to be in the range of values 1.211=1.256, and the volumetric 1.626=1.867. The maximum values of these coefficients during the burn-up time are $\rm K_r$ =1.283 and $\rm K_v$ =1.905.

Calculations were also performed with the BIPR program for a system of rearranging assemblies during rechargings, which was proposed in [5] (see Tables 1 and 2). The initial values for the radial and volumetric coefficients of nonuniformity in this case are, respectively, 1.281-1.318 and 1.673-1.992. The maximum values are 1.325 and 1.992.

When the data from the two series of calculations were compared it was found that, as a result of optimization in the fuel charges under consideration, as compared with the data in [5], a reduction is achieved of 2.6-6.7% for the initial values and 1.8-4.5% for the maximum values of the coefficient of nonuniformity of energy

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distribution over the burn-up period. Along with this, there is a 4.4% reduction in the maximum value of the coefficient of volumetric nonuniformity of energy distribution, the depth of burn-up of the 3.6%-enriched fuel is increased, and the reactor's total energy production for the seven runs rose by about 1%.

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CSO: 8144/1895

THERMOHYDRAULIC AND PHYSICOCHEMICAL PROCESSES IN NUCLEAR POWER PLANTS

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA I ORDENA OKTYABR'SKOY REVOLYUTSII ENERGE-TICHESKOGO INSTITUTA, TEMATICHESKIY SBORNIK: TEPLOGIDRAVLICHESKIYE I FIZIKO-KHIMICHESKIYE PROTSESSY V YADERNYKH ENERGETICHESKIKH USTANOVKAKH in Russian No 474, 1980 (signed to press 20 Jun 80) pp 2, 173-182

[Annotation and abstracts of articles from book "Proceedings of Moscow Power Institute Honored by the Order of Lenin and the Order of the October Revolution, Collection of Papers on Thermohydraulic and Physicochemical Processes in Nuclear Power Plants", edited by F. A. Gorbatykh, Moskovskiy energeticheskiy institut, 600 copies, 182 pages]

[Text] A collection of 28 articles on research done at the department of nuclear electric plants of Moscow Power Institute. These articles present materials on topical problems in power engineering: reliability and safety of nuclear electric plants in loss-of-coolant accidents; water chemistry and cleaning of equipment surfaces; corrosion resistance of structural materials under various thermophysical and chemicophysical conditions; reactor calculations: axial profile of energy release with continuous movement of fuel; compact shielding configurations; kinetics of water radiolysis under power reactor core conditions; universal mathematical model for calculating thermal arrangements of nuclear electric plants and nuclear heat and power stations.

The materials of the collection will be of interest to specialists dealing with nuclear power.

UDC: 621.311.25:621.039

INVESTIGATION OF DYNAMICS OF BOILING COOLANT TEMPERATURE UPON LOSS OF VESSEL INTEGRITY

[Abstract of article by Dement'yev, B. A., Kuznetsov, V. D., Skotnikov, A. P. and Ionov, B. A.]

[Text] The article gives the results of investigation of the dynamics of temperature of a two-phase medium upon loss of integrity of a pressure vessel in the case of unilateral and bilateral coolant leakage. An estimate is given of the dynamic characteristics of the thermocouple and the influence that conditions of heat exchange of the thermocouple with the two-phase medium and the vessel wall has on

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readings when recording temperatures. Based on the resultant data, a conclusion is drawn regarding the thermodynamic state of the steam-power mixture during leakage, which is important in mathematical modeling of the process.

UDC: 621.311.25:621.039

ANALYSIS OF DATA ON TWO-PHASE FLOWRATE FOR VARIABLE PARAMETERS

[Abstract of article by Dement'yev, B. A., Ionov, B. A., Kuznetsov, V. D. and Nikol'skaya, N. A.]

[Text] The paper analyzes the influence of various factors (steam content, rate of pressure reduction, parameters preceding the discharge branch) on the specific flowrate of a steam-water mixture upon loss of integrity of a pressure vessel. An estimate is given of the error of calculation of the volumetric steam content during the process of loss of coolant.

UDC: 621.311.25:621.039

TEMPERATURE CONDITIONS OF VVER REACTOR FUEL ELEMENTS DURING AFTERCOOLING

[Abstract of article by Kabanov, L. P. and Nikonov, S. P.]

[Text] The paper gives calculations of temperature conditions of the fuel elements of a VVER reactor on the aftercooling stage. Principal characteristics of heat transfer processes with repeated wetting were calculated by empirical formulas based on processing experimental data of Moscow Power Institute. As a result of calculations, the cooling water flowrates are determined that keep the fuel element cladding temperature below the limiting level.

UDC 541.15:539.12.04

KINETICS OF WATER RADIOLYSIS UNDER POWER REACTOR CORE CONDITIONS

[Abstract of article by Milayev, A. I.]

[Text] It is shown that fast ($t \approx 10^{-3}-10^{-2}$ s) and slow ($t \approx 10$ s) processes occur upon irradiation of water. The slow process is due to reactions giving rise to H_2 , O_2 or H_2O_2 . For example for hydrogen peroxide this might be the reaction

 $H_2 + HO_2 \rightarrow H_2O_2$.

The same reaction explains the existence of $\rm H_2O_2$ at high temperatures (up to 610 K) of the irradiated water.

UDC 621.311

THERMODYNAMIC ANALYSIS OF IRON COMPLEXATE STABILITY IN AQUEOUS SOLUTION

[Abstract of article by Monakhov, A. S., Voronov, V. N., Kotenkov, V. N., and Mayorov, M. F.]

[Text] The article gives the results of calculation of thermodynamic stability of iron complexates with EDTA anion, using initial data on the complexate

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concentration and stability constants. The results of calculation agree well with previous experimental data, demonstrating the efficacy of the proposed technique.

UDC 620.193.001.5

INFLUENCE OF AQUEOUS COOLANT ELECTRICAL CONDUCTIVITY ON CORROSION MECHANISM IN STEEL-ALUMINUM JOINTS

[Abstract of article by Gradusov, G. N., Zhurenkov, B. A.Morozov, A. V. and Frolov, N. G.]

[Text] The authors give the results of investigation of the process of interaction between steel-aluminum welds and low-temperature aqueous coolant at various values of pH and specific conductivity. It is shown that foci of localized corrosion in the form of isolated pits appear on the weld surface and in the aluminum alloy zone of the welded joints if the specific conductivity of the coolant exceeds $5 \cdot 10^{-6}$ S/cm.

UDC 621.039.534.4:734.001.5

TECHNIQUE FOR DEPOSITING POWDERED TITANIUM DIOXIDE ON THE VERTICAL FILTERING ELEMENT OF A PLACER FILTER

[Abstract of article by Kuz'menko, N. A., Sharygin, L. M. and Shtin, A. P.]

[Text] An investigation is made of conditions of homogeneous formation of a filtering layer from powders with specific weight of $2.5 \cdot 10^3$ kg/m³ and granularity in the range of 25-150 μ m. It is shown that it is possible in principle to produce a uniform deposit on a candle filter cartridge of materials distinguished by high specific weight and large fractional inhomogeneity of particles. The technique and conditions of the deposition process are worked out.

UDC 621.311:621.39

UNIVERSAL MATHEMATICAL MODEL FOR CALCULATIONS OF THERMAL ARRANGEMENTS OF NUCLEAR ELECTRIC PLANTS AND NUCLEAR HEAT AND POWER STATIONS

[Abstract of article by Zorin, V. M. and Bisyarin, A. N.]

[Text] A mathematical model is developed for calculations of the thermal arrangements for nuclear electric plants and nuclear heat and power stations with arbitrary number and location of components. Physical and logic parameters are standardized, as are the computational elements of the model. Adiabat equations are given for superheated and saturated steam in the form of relations for final enthalpy as a function of initial pressure and enthalpy and final pressure.

UDC 621.039.5

NATURAL COOLANT CIRCULATION IN PRIMARY CIRCUITS OF NUCLEAR HEAT AND POWER STATIONS AND NUCLEAR TRANSPORT FACILITIES

[Abstract of article by Gorburov, V. I.]

[Text] The author considers the feasibility of using natural circulation of the coolant in boiling-water reactors for nuclear heat and power stations and nuclear

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transport facilities. An analysis is made of capabilities for getting different modes of circulation for some combinations of geometric and thermophysical parameters of the circuit and the coolant. Advantages and disadvantages of the circulation modes are compared as well as some ways to calculate these parameters.

UDC 621.039.53

SOME ASPECTS OF PIT CORROSION OF PEARLITE STEEL

[Abstract of article by Tolstykh, A. N., Belous, V. N. and Khafizov, I. A.]

[Text] The paper gives the results of studies of pit corrosion of grade 20 steel. It is noted that there is an initial accelerated stage of growth in the depth of the pits, that subsequently slows down. It is shown that the depth of the pits on the surface of specimens after 3,300 hours of tests exceeds 160 $\mu \rm m$, and reaches 250 $\mu \rm m$ under conditions with intermediate shutdowns. Analytical relations are given for the increase in depth of pitting corrosion.

UDC 621.039.53

CORROSION AND CARRY-OFF OF CORROSION PRODUCTS OF PEARLITE STEEL AS APPLIED TO TECHNOLOGICAL PARAMETERS OF RBMK LOW-PRESSURE HEATER

[Abstract of article by Gromova, A. I., Tolstykh, A. N., Izmodenov, Yu. A. and Manayenkov, Yu. G.]

[Text] The article gives the results of corrosion tests of grade 20 pearlite steel that were done in a carbon loop in an atmosphere of condensate and saturated steam. It is shown that the rate of corrosion of grade 20 steel in condensate after 3,300 hours of testing under nominal conditions reaches 0.039 g/($m^2 \cdot hr$), and with intermediate 500-hour shutdowns--0.070 g/($m^2 \cdot hr$). The carry-off of corrosion products amounts to 60% and 70% respectively. Pitting corrosion of the metal surface is noted.

UDC 621.311.25:521.039.002.5

CORROSION STUDIES OF ALUMINUM ALLOY UNDER THERMAL LOADING

[Abstract of article by Rassokhin, N. G., Kolobneva, L. I., Kuznetsov, A. D., Lipanina, A. A., Ismagilov, R. Sh., Golosov, O. A., and Manayenkov, Yu. G.]

[Text] An examination is made of the results of a study of aluminum alloys of the Al-Fe-Ni system under dynamic conditions at a coolant pressure of 6.86 MPa (70 kgf/cm 2) and saturation temperature in corrosionless water chemistry. An analysis is made of the corrosion behavior of the investigated alloys as a function of temperature and aggregate state of the coolant in testing specimens under thermal loading.

UDC 620.193.001.5

INTERACTION OF ALUMINUM-STEEL WELDS WITH LOW-TEMPERATURE AQUEOUS COOLANT FLOW

[Abstract of article by Gradusov, G. N., Gumileva, M. G. and Morozov, A. V.]

[Text] The article gives methods and results of studying processes of interaction between steel-aluminum butt welds and moving aqueous coolant at temperatures up to 130°C. The studies were done on the basis of tests lasting 10,000 hours. It is shown that butt-welded contact between dissimilar construction materials does not lead to foci of local destruction.

UDC 621.039.53:620.194.2.001.5

USING COMPUTERS TO EXPAND THE APPLICATION OF QUANTITATIVE EVALUATION OF CORROSION CRACKING

[Abstract of article by Rassokhin, N. G., Gorbatykh, V. P., Gerngros, M., Yorike, D. and Khofman, V.]

[Text] The article gives computational formulas, computer programs and a nomogram plotted from the results of calculations for estimating the time to corrosion cracking of grade 18/8 steel as a function of concentration of chlorine ion, oxygen, working temperature, metal thickness and mechanical stresses.

UDC 621.181.61:621.311.25:621.039.001.5

TECHNICAL-ECONOMIC ANALYSIS OF THE FEASIBILITY OF CONDENSATE-CLEANING FACILITIES IN NUCLEAR ELECTRIC PLANTS WITH VVER REACTORS

[Abstract of article by Monakhov, A. S., Voronov, V. N., Dik, V. P. and Lebedev, V. A.]

[Text] An examination is made of optimum conditions for using condensate cleaning depending on the type of cooling water and water chemistry standards. It is shown that for a number of rivers in the European part of the USSR, condensate cleaning is advisable from the technical-economic standpoint. The optimum version is 100% condensate cleaning. Data are given on specific types of nuclear electric plants and cooling waters.

UDC 621.039.58

USING THE DIFFUSION-REMOVAL METHOD TO CALCULATE A TEST PROGRAM ON BIOLOGICAL SHIELDING

[Abstract of article by Mikhay, K.]

[Text] The paper gives the results of comparison of data of calculation of neutron transmission through compact shielding configurations by the diffusion removal method with the results of measurement of neutron fluxes by integral threshold detectors on the teaching reactor at Budapest Technical University. It is shown that the diffusion-removal method can be successfully used for calculating compact shield configurations.

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UDC 621.039.58

USING METHOD OF INTEGRAL KINETIC EQUATIONS TO CALCULATE MULTILAYER SHIELDING

[Abstract of article by Mikhay, K.]

[Text] An examination is made of an improved method of one-dimensional calculation of biological shielding based on combining the integral equation method with the diffusion approximation, considering inhomogeneity of distribution of neutron sources. An attempt is made to account for the actual three-dimensional structure of the field of neutron sources. The results of the calculation were compared with results of changes in test problems simulating multilayered shielding.

UDC 621.1.013.537

COMPUTATIONAL FORMULA FOR DETERMINING MULTIPLICITY OF CIRCULATION

[Abstract of article by Raz'nyak, V.]

[Text] The author attempts a departure from consideration of steam generation as a discrete process. Interpretation of this process as continuous yields analytical expressions for multiplicity of circulation $K_{\rm C}$. The results of calculations of $K_{\rm C}$ are compared with published experimental data.

UDC 621.311.25:621.039

EXPERIENCE WITH HIGH-TEMPERATURE RINSING

[Abstract of article by Tevlin, S. A., Bogatyreva, S. V., Nosacheva, S. I. and Krivov, I. V.]

[Text] The proposed method of cleaning surfaces with complexon solutions can be used to remove deposits from heat-transfer surfaces in the presence of high thermal flux (1 MW/cm^2). A reduction is noted in the rate of growth of deposits after rinsing. The authors verify the feasibility of concentrating active wastes of rinsing by using ion-exchange resins.

UDC 621.039.621.187.4:536.5.019.001.5

INFLUENCE OF POROUS IRON OXIDE DEPOSITS ON HEAT-EXCHANGE CONDITIONS ON HEATED SURFACES

[Abstract of article by Krivov, I. V. and Alkhutov, Ye. V.]

[Text] It is shown that formation of porous iron oxide deposits during boiling does not increase the temperature of the heat-transfer surface thanks: to the specific structure of the deposits. Deposit formation causes a shift in the limit of onset of surface boiling toward the coolant underheating region.

UDC 621.039.53:620.194.2.001.5

MODELING QUASISTEADY HEAT FLOW ON ELECTRICALLY HEATED FUEL ELEMENT SIMULATORS

[Abstract of article by Gorbatykh, V. P., Yorike, M., Kislov, G. I. and Gramatikov, P. S.]

[Text] In simulating thermochemical conditions of fuel element cladding in nuclear reactors, it is sometimes necessary to account for the arisal of quasisteady heat flow for studying hydrodynamics, heat exchange and corrosion. In the case where specimens that are electrically heated by alternating current are used, the quasisteady state can be simulated by an oscillator described in this paper, using thyristorized RNTO controllers for voltage regulation.

UDC 621.384.039

ANALYSIS OF DESIGN RECOMMENDATIONS ON THE HEAT EXCHANGE CRISIS FOR DETERMINING PERMISSIBLE POWER OF VVER-440 REACTOR

[Abstract of article by Bartolomey, G. G., Kharitonov, Yu. V and Tsimmer, E.]

[Text] The article compares the most widely used design recommendations on the heat exchange crisis for coolant boiling in the fuel assembly of the VVER-440 reactor. Data are given on changes in the reserve factors K and the true reserves with respect to the crisis $S_{\mathbf{w}}$ for reactor operating conditions with unsteady circulation of the coolant as a result of failure of two and three of the six main circulating pumps.

UDC 621.181.532.5

CALCULATION OF TRUE VOLUMETRIC STEAM CONTENT

[Abstract of article by Skachek, M. A. and Borzdov, Ye. G.]

[Text] An examination is made of a method of extending the range of applicability of the VTI [Heat-Engineering Institute] formula for calculating the average volumetric steam content under conditions of bubbling and forced circulation. It is shown that under certain conditions the accuracy of the calculation can be improved and the VTI formula can be used for practically any channel diameter by using the limiting diameter of the channel instead of the true diameter in the correction complex of the VTI formula.

UDC: 621.311.25:621.039

ACOUSTIC DIAGNOSIS OF BOILING UNDER PROCESS NOISE CONDITIONS

[Abstract of article by Ratnikov, Ye. F., Vlasov, V. I., Radchenko, R. V., Shagalov, A. G. and Ismagilov, R. Sh.]

[Text] The authors give a method of detecting boiling that is based on localizing acoustic emission of the onset of vapor bubbles. The paper shows the dynamic behavior of noise spectra in the heat-release channel for weak and strong background of processes noises, and also the feasibility of diagnosing conditions of weak and developed boiling from spectral characteristics.

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UDC: 621.311.25:621.039

CALCULATING DEFORMATIONS OF FUEL ELEMENT CLADDING IN A LOSS-OF-COOLANT ACCIDENT

[Abstract of article by Nevzorov, P. F.]

[Text] The paper compares available experimental data on the temperature of bursting of cladding as a function of internal pressure. For the transient process typical of a loss-of-coolant accident, the results of cladding deformation calculation are given. The results of the calculation agree satisfactorily with experimental data.

UDC: 621.311.25:621.039

REPEAT WETTING IN TUBES WITH COOLING BY FILM RUNOFF AND BY PRESSURIZED DOWNFLOW

[Abstract of article by Kabanov, L. P. and Khachatryan, O. M.]

[Text] Experimental data are given at parameters of: pressure 0.1 and 0.5 MPa, mass flowrate $25 < gw < 250 \text{ kg/(m}^2 \cdot s)$, underheating of water at inlet to the working section 0-80 K, wall temperature 673-1073 K, generated heat loads with consideration of losses 0-40 kW/m², in stainless steel and zirconium alloy tubes 3.525 m long. Differences are determined between conditions of cooling by film runoff and pressurized downflow, and the conditions of deceleration of the runoff film.

UDC 621.039.52.034.3

ANALYTICAL METHOD OF CALCULATING AXIAL PROFILE OF ENERGY RELEASE IN REACTOR WITH CONTINUOUS FUEL MOTION

[Abstract of article by Alkhutov, M. S. and Kantor, T.]

[Text] The article proposes an analytical method for determining the axial profile of energy release in a reactor with continuous motion of fuel. The algorithm and final form of solution are given. Comparison is made with the exact solution.

UDC 621.039.5:621.039.53

INTENSIFICATION OF FORCED COOLANT OSCILLATIONS IN CIRCULATION LOOP WITH VARIABLE COOLANT COMPRESSIBILITY

[Abstract of article by Proskuryakov, K. N.]

[Text] Results of theoretical calculations are given as a formula for calculating the gain of oscillations acting on a coolant. The relation for intensification of oscillations as a function of geometric and flow parameters of the hydraulic system can be used in designing stationary and transport facilities, and also for seismic effects.

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NON-NUCLEAR ENERGY

UDC 538.4

GENERAL AND THEORETICAL MAGNETOHYDRODYNAMICS

Salaspils DESYATOYE RIZHSKOYE SOVESHCHANIYE PO MAGNITNOY GIDRODINAMIKE: I. OB-SHCHIYE I TEORETICHESKIYE VOPROSY MGD (TEZISY DOKLADOV) in Russian 1981 (signed to press 24 Feb 81) pp 222-231

[Table of contents from book "Tenth Riga Conference on Magnetohydrodynamics: General and Theoretical Problems of MHD (Abstracts of Reports)", Institute of Physics, LaSSR Academy of Sciences, 500 copies, 231 pages]

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MAGNETOHYDRODYNAMIC MACHINES

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RELIABILITY PREDICTION AND DIAGNOSIS OF POWER EQUIPMENT

Moscow TRUDY MOSKOVSKOGO ORDENA LENINA I ORDENA OKTYABR'SKOY REVOLYUTSII ENERGE-TICHESKOGO INSTITUTA, TEMATICHESKIY SBORNIK: SPETSIAL'NYYE VOPROSY PROGNOZIROVANIYA NADEZHNOSTI I DIAGNOSTIKI ENERGETICHESKOGO OBORUDOVANIYA in Russian No 501, 1980 (signed to press 14 Jan 81) pp 2, 149-158

[Annotation and abstracts of articles from book "Proceedings of Moscow Power Institute Honored by the Order of Lenin and the Order of the October Revolution, Collection of Papers on Special Problems of Reliability Prediction and Diagnosis of Power Equipment", edited by G. S. Vargin, Moskovskiy energeticheskiy institut, 500 copies, 158 pages]

[Text] This collection contains the results of research by the department of electric machines, the department of electric transportation, the power machinery faculty, and also the department of electric machines of the Smolensk Affiliate of Moscow Power Institute.

The collection deals with problems of predicting reliability of electric machines and systems, diagnosis of the condition and workability of different components, and with individual reliability prediction. Research results are given in the area of parametric reliability, and diagnosing components of pulse-thyristor converters of rolling stock of municipal surface transport. In addition, an examination is made of problems of accelerated tests, and reliability of mechanical components of electric equipment.

The purpose of this collection is to generalize research results in the area of reliability, prediction, and diagnosis of power equipment, and to project future work in this area.

Docent N. D. Kuznetsov of the department of electric machines prepared and edited the manuscript.

UDC 621.3131.62.019.3

EVALUATING QUALITY AND RELIABILITY OF ELECTRIC MACHINES ON THE DESIGN STAGE BY MONTE CARLO METHOD

[Abstract of article by Kopylov, I. P. and Golubovich, A. I.]

[Text] It is shown that at estimate can be made of the influence that some parameters associated with change in technology, use of materials and the like can have

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on the principal characteristics of machines without using full-scale tests on the stage of coming up with an algorithm for machine design.

UDC 621.313.322.62.019.3

IMPROVING RELIABILITY OF ELECTRIC PLANTS UNDER OVERLOADS

[Abstract of article by Smolenskiy, A. V., Panchenko, V. P., Shaferyuk, A. I. and Lapchenko, P. I.]

[Text] A method is developed for matching the overload characteristics of an object protected from overload and the characteristics of the protection device. The method can be extended to any electrical device where temperature is the overload criterion. The principle of designing a protective device is discussed.

In introducing this method of protection, a considerable economic effect can be achieved by more complete utilization of the overload capacity of thyristors.

UDC 621.8.038:62-752

DETERMINING ORDERS OF MAGNETIC VIBROPERTURBING FORCES

[Abstract of article by Astakhov, N. V., Polukhin, V. F. and Il'ina, N. N.]

[Text] An analysis is made of known methods of determining the order of magnetic vibroperturbing components. It is shown that existing contradictions cannot be resolved within the framework of accepted models. It is proposed that a change be made from lumped components to continuously distributed radial loads, as the determination of deformations has been fairly well worked out for such loads.

UDC 621.165

CALCULATING DYNAMIC STRESSES IN WORKING BLADES OF ARBITRARY HEIGHT

[Abstract of article by Samoylovich, G. S. and Antipin, A. V.]

[Text] A method is proposed for calculating dynamic stresses in working blades of turbines with consideration of the influence of secondary flows on inhomogeneity of the velocity field behind the guide blading.

UDC 621.833

STAND TESTS OF GEAR TRAIN DYNAMICS

[Abstract of article by Yershov, V. I., Kozintsov, B. P., Piksin, Yu. I. and Shuklin, Yu. A.]

[Text] The article describes a stand for dynamic tests of gear trains.

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UDC 539.412:620.172

CHOOSING OPTIMUM CRITERION FOR EVALUATING UNIFORM DEFORMATION UNDER UNIAXIAL TENSION

[Abstract of article by Baranov, V. V.]

[Text] An analysis is made of different methods of estimating uniform relative contraction for specimens made of ductile materials.

UDC 621.039.534.25:621.039.58

CUMULATIVE MODEL OF FAILURES FOR SYSTEMS OF A LARGE NUMBER OF COMPONENTS OF THE SAME TYPE

[Abstract of article by Chernov, V. K.]

[Text] An examination is made of problems of evaluating the reliability of structural elements of nuclear reactors that contain a large number of fuel elements or heat-exchanging components.

UDC 621.039.5:042.7

CALCULATING RELIABILITY OF STRUCTURAL COMPONENTS OF POWER FACILITIES FOR SEISMIC EFFECTS BY THE METHOD OF MOMENT FUNCTIONS

[Abstract of article by Chirkov, V. P. and Shcherbakov, A. N.]

[Text] An algorithm is presented for dynamic calculation of structural elements of power facilities for seismic effects with consideration of nonlinear properties.

UDC 621.757

OPTIMIZING THE CONFIGURATION OF ITEMS WITH ACCURACY ASSURANCE BY GROUP INTERCHANGE-ABILITY METHOD

[Abstract of article by Moroz, S. F. and Chugunov, V. I.]

[Text] An examination is made of the problem of dynamic optimization of the work of the assembly section of a machine building plant. Algorithms are developed that guarantee smooth operation of assembly departments and uniformity of the accuracy characteristics of items.

UDC 629.113.6:621.119

AREAS IN SCIENTIFIC RESEARCH AND DEVELOPMENT OF SYSTEMS FOR DIAGNOSING ROLLING STOCK OF MUNICIPAL ELECTRIC SURFACE TRANSPORT

[Abstract of article by Yefremov, I. S. and Ozhigin, V. P.]

[Text] An examination is made of major trends in developing systems for trouble-shooting rolling stock in municipal electric transport systems. Information is given on experimental diagnostic stands for streetcars and trolley buses.

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The development of multipurpose diagnosis facilities and automation of the troubleshooting process will provde the basis for developing an automated system for controlling the state of rolling stock of a municipal electric transport system.

UDC 621.337.1

DEVELOPMENT OF FACILITIES FOR TROUBLESHOOTING THE ELECTRONIC EQUIPMENT OF THE RVZ-7 STREETCAR

[Abstract of article by Kos'kin, O. A. and Nikolayev, V. F.]

[Text] A system of equipment is proposed for diagnosing the pulse-thyristor converter of a streetcar. The system is based on series 140 and 155 integrated circuits.

UDC 621.337.1

EXPERIMENTAL STUDIES OF RELIABILITY OF PULSE-THYRISTOR CONTROL SYSTEM OF RVZ-7 STREETCAR

[Abstract of article by Yefremov, V. I., Karasev, S. I. and Khomenko, S. V.]

[Text] A method is proposed for experimental studies of reliability of the pulse-thyristor control system of the RVZ-7 streetcar. The time of fail-free operation of the stabilized voltage unit in the pulse-thyristor control system is determined.

UDC 621.214.1

RESULTS OF RESEARCH AND DEVELOPMENT OF INTEGRATED-CIRCUIT DEVICE FOR DIAGNOSING A CONTROL SYSTEM FOR A TROLLEY BUS

[Abstract of article by Kosarev, G. V., Glushenkov, V. A. and Komarov, V. G.]

[Text] Devices are proposed for troubleshooting the control system of the pulsethyristor converter of a trolley bus. Operation of the devices is experimentally checked under operating conditions of the trolley bus with pulse-thyristor converter.

UDC 621.335.43:651.53

SELECTION OF CONTROL POINTS FOR TROUBLESHOOTING TROLLEY BUS CONTROL SYSTEM

[Abstract of article by Arshinov, S. A.]

[Text] An examination is made of questions of practical selection of control points in the control system of the ZIU-682B trolley bus for purposes of checking working condition, finding problems, and forecasting the technical state of its equipment.

UDC 656.132:658.53

STAND FOR DIANOSING TECHNICAL STATE OF TROLLEY BUSES

[Abstract of article by Aksenov, N. D.]

[Text] The paper gives the capabilities of a dynamic stand for functional diagnosis of trolley buses. The design is described, and the functional purpose is given for the major components and subassemblies of the stand and electric circuit.

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IDC 621.313.333:621.3.042.001.5

CALCULATING VIBROPERTURBING FORCES OF INDUCTION MOTOR IN CASE OF ECCENTRICITY

[Abstract of article by Malyshev, V. S., Tityukhin, N. F. and Kotarba, Z.]

[Text] A method is given for calculating vibroperturbing forces in the case of eccentricity. A recommendation is made on the advisable number of terms in the function expansion. Values of the coefficients of the expansion are given.

UDC 621.313.322:616-07

DIAGNOSING THE STATE OF COMPONENTS OF THE INTERNAL PROTECTION SYSTEM FOR THE STATOR WINDINGS OF A HIGH-VOLTAGE HYDROGENERATOR

[Abstract of article by Abramov, A. I., Izvekov, V. I. and Serikhin, N. A.]

[Text] The paper describes a technique for diagnosing internal protection of the stator winding of a high-voltage hydrogenerator. This method was used in certification tests of the machine for the Skhodnya Hydroelectric Plant. Electric circuit schematics are given for the measurement equipment, and recommendations are made on selection of components.

UDC 0621.3.3.333:62.014.3

ACCOUNTING FOR EFFECT OF TRANSIENT PROCESSES ON RELIABILITY OF WINDING INSULATION OF INDUCTION MOTORS

[Abstract of article by Vanigasuriy, D. G.]

[Text] A method is proposed for calculating electrodynamic forces in transient processes in the end parts of a single-layer concentric stator winding to develop a mathematical model for predicting the reliability of an induction motor operating under frequent startup conditions. The paper gives the time dependence of starting forces, and the dependence of absolute maximum values of force at different starting times.

UDC 621.214,632:658.562.001.5

DIAGNOSING SEMICONDUCTOR POWER RECTIFIERS IN CONVERSION UNITS

[Abstract of article by Kalashnikov, B. G. and Stremovskaya, G. P.]

[Text] An examination is made of a method of estimating the load capacity of semiconductor power rectifiers by measuring the temperature increment of the p-n junction under certain constant test conditions.

UDC 621.337.1

PREDICTING RELIABILITY OF PULSE-THYRISTOR CONTROL SYSTEMS BY NONLINEAR PHYSICAL MODELING METHOD

[Abstract of article by Yefremov, V. I.]

[Text] A method is developed for predicting the reliability of control systems of pulse-thyristor converters. The time of fail-free operation of the voltage stabilization unit of the pulse-thyristor control system is determined.

UDC 656.132

PREDICTING INSULATION RELIABILITY OF TROLLEY BUS ELECTRIC EQUIPMENT

[Abstract of article by Chichibaba, V. F.]

[Text] Data are analyzed on the failure of insulation of trolley bus electric equipment. A method is proposed for predicting reliability of the insulation of electric equipment of transport facilities.

UDC 530.17,519.245+62:001.18

STOCHASTIC SIMILARITY AND FORECASTING PROBLEMS

[Abstract of article by Gordiyevskiy, I. G. and Kavchenko, G. P.]

[Text] It is shown on the basis of examples in the article that the use of stochastic similarity and modeling yields fruitful results in solving forecasting problems: in synthesizing a sound technique for evaluating mathematical models for prediction, and in improving the accuracy of results of this technique.

UDC 621.313.2:62.001.18:62.019,3

INDIVIDUAL FORECASTING OF RELIABILITY OF ELECTROMECHANICAL ENERGY CONVERTERS

[Abstract of article by Kuznetsov, N. L. and Danilov-Nitusov, A. N.]

[Text] An examination is made of major points in a system for individual reliability prediction based on pattern recognition theroy, and in particular, one of the main points--solution of the problem of compiling a vocabulary of forecasting features.

UDC 621.313:616-017

SOLVING PROBLEMS OF DIAGNOSING ELECTRIC MACHINES IN THE EM AUTOMATED DESIGN SYSTEM

[Abstract of article by Dmitriyev, M. M. and Zaytsev, A. I.]

[Text] An examination is made of an automated design system based on the SM-1 complex and information display device of Orion type for shortening time in designing

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electric induction motors, producing technical documentation, processing test results and diagnosing an item. The proposed system assumes automation of up to 60% of planning and design work.

UDC 7.021.2:62.001.18:62.019.3:530.17

USING SCALING THEORY TO SYNTHESIZE GENERALIZED MODELS OF RELIABILITY PREDICTION

[Abstract of article by Gordiyevskiy, I. G., Kavchenko, V. P., Petrov, V. S. and Stepanov, Yu. K.]

[Text] This method of determining reliability characteristics of analog objects provides for refinements by combining forecasting data with results found in tests and in operation assuming that they are stochastically similar.

UDC 621.8.038:62-752

CALCULATION OF VIBROFERTURBING DISPLACEMENT OF INDUCTION MOTOR LUGS

[Abstract of article by Malyshev, V. S., Nesterova, N. G., Medvedev, V. T. and Kotarba, Z.]

[Text] A method is given for determining vibroperturbing displacement of lugs of an induction motor. An algorithm is proposed for forming the coefficients of the equation, and numerical values are given.

UDC 621.313.2:62.001.18:62.019.3

PREDICTING RELIABILITY OF COLLECTOR UNIT OF ELECTRIC MACHINES

[Abstract of article by Kuznetsov, N. L. and Ryzhenskaya, B. M.]

[Text] Data of endurance tests of the collector unit of DC machines are used as a basis for demonstrating the feasibility of individual reliability prediction by test diagnosis, as well as calculation and prediction of necessary parameters to ensure required reliability (reliability assurance).

UDC 621.822.8

STAND DIAGNOSIS OF LARGE ROLLER BEARINGS (120 \leq d_{shaft} \leq 200 mm)

[Abstract of article by Baranov, V. V., Frolov, A. G. and Shuklin, Yu. A.]

[Text] The paper gives the results of stand tests of large roller bearings for detecting items with defects.

UDC 621.791.94

INFLUENCE OF MECHANICAL DRIVE PARAMETERS ON RELIABILITY OF HIGH-QUALITY OPERATION OF PORTAL THERMAL CUTTING MACHINES

[Abstract of article by Kudryavtsev, Ye. P.]

[Text] The author considers the effect of mechanical drive parameters on cutting accuracy and discusses methods of optimizing these parameters.

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UDC 621.642.39:513.75

AFFINE MODELING OF STRESS-STRAIN STATE OF MULTILAYERED CYLINDRICAL SHELL

[Abstract of article by Batishev, M. I. and Salatov, A. V.]

[Text] The paper investigates possibilities of synthesizing affine models by satisfying most significant dimensionless criteria.

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INDUSTRIAL TECHNOLOGY

UDC 62-50

ADAPTIVE CONTROL OF DYNAMIC SYSTEMS

Moscow ADAPTIVNOYE UPRAVLENIYE DINAMICHESKIMI OB"YEKTAMI in Russian 1981 (signed to press 10 Jun 81) pp 2-10

[Annotation, table of contents and foreword from book "Adaptive Control of Dynamic Systems", by Vladimir Nikolayevich Fomin, Aleksandr L'vovich Fradkov and Vladimir Andreyevich Yakubovich, Izdatel'stvo "Nauka", 3900 copies, 448 pages]

[Text] This book is devoted to one of the new areas of cybernetics: adaptive system theory. Methods of analysis and synthesis of adaptive regulators are studied which assure achievement of the control objective under conditions of slight information on the control system and the properties of external actions. The main attention is devoted to approaches arising in recent years and dealt with only in journal literature. The methods of recurrent specific inequalities, stochastic recurrent evaluation and velocity gradient are examined in detail.

The book is intended for engineers, scientific personnel in the field of industrial cybernetics and mathematics, and instructors and students of advanced VUZ courses interested in adaptive system theory and its applications.

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Foreword

This monograph presents methods of controlling a dynamic system under conditions where a series of substantial parameters and factors determining its behavior are unknown. The required control law is sought by an adaptive regulator in the operation process from the system's reactions to the controlling actions supplied. As soon as such a regulator is constructed, the entire system acquires the property of adaptability: if the previously found control law ceases to be satisfactory given a change in external conditions (this becomes known from the system's behavior), then the adaptive regulator finds a new control law, with which the system's behavior again begins to satisfy the required criteria. (The terms "control law" and others are, of course, subject to a precise definition.)

The development of adaptive system theory is being stimulated by the requirements of current technology. Practice provides an abundance of problems of controlling various types of objects given one or another degree of ignorance regarding the control system, its operating conditions, and disturbances. Adaptive control methods are being increasingly used in solving a series of aerospace technology problems, in controlling industrial processes, and in various sectors' automatic control systems. The general use of computer technology, which creates greater possibilities for achieving adaptation algorithms, is stimulating adaptive methods' extensive introduction into practice.

Adaptive system theory is currently in a formation stage. Many different opinions, directions and methods exist. This monograph essentially represents

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the direction developed by this book's authors. The basic original results presented were formulated during the authors' joint work at a seminar in the department of theoretical cybernetics of the mathematico-mechanical school of Leningrad University and a seminar on adaptive systems at the LOSNTO [expansion unknown]. Existing monographs on adaptive system theory do not overlap much with this book's material.* The authors have not tried to give a historical review of the special literature. A number of important and interesting studies tangential to the monograph's main theme have not been mentioned.

The analysis of various engineering methods developed in the theory of self-adjusting control systems has been very fruitful for the development of adaptive system theory. In the current general understanding of the term "adaptive control system", a self-adjusting system belongs to the class of adaptive ones. This book attempts to present adaptive control theory as a consistent mathematical theory beginning with a formal definition of an adaptive system. Methods of designing actual systems are not examined.

Striving for simplicity of explanation and mathematical strictness at the same time, and aiming primarily at readers with an engineering background, the authors in the basic text devote their main attention to the conceptual aspect, attempting to explain the "recipe" for constructing adaptive control algorithms. The proofs are written concisely; they are separated into individual paragraphs, and their reading presupposes a certain mathematical training. Necessary supplementary information and more complicated results are provided in the chapter appendices.

The authors hope that the book will also be of interest to mathematicians. The problem of adaptive control, as it is treated in this book, is essentially a new mathematical problem of defining an unknown function (it is an unknown control law) in a unique and nonstandard situation. In contrast to the ordinary extrapolation problem, where the function must be constructed from its values in predetermined points, the function here must be reconstructed from very indirect information on the "quality" of its current approximation.

Using the adaptive control synthesis methods presented in the book (in particular, using the recurrent criterial inequality method), a series of concrete applied problems are solved. Unfortunately, an explanation of these problems and their solutions was not possible within the scope of this book, since this would have required a substantial increase in its volume. Solutions to several important adaptation problems also could not be presented; the reader will find information on them and on certain solved applied problems in the commentaries and the literature at the end of the book.

Enumeration of formula is conventional. For example, within chapter 5 a reference (3.12) means the 12th formula from section 5.3.

*The monographs "Applied Theory of Discrete Adaptive Control Systems" by D. P. Derevitskiy and A. L. Fradkov and "Adaptive Control" by V. G. Sragovich, put out by the "Nauka" publishing house in 1981, deal with this book's subject matter. The former has a more practical orientation, while the latter provides a survey of the current state of adaptation theory, primarily adaptive control of Markov processes.

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A triple numeration is used for references to a formula in other chapters: (1.3.14) means formula (3.14) from chapter 1.

At the end of the book is a list of basic abbreviations and symbols.

The authors' work in presenting the book's material was distributed in the following manner: chapters 1 and 4 and sections 2.1, 3.1 and 3.2 were written by V. A. Yakubovich; chapters 5 and 6 and sections 2.2, 2.3, 3.3 and 3.P were written by V. N. Fomin; and chapter 7 and section 2.4 were written by A. L. Fradkov. The book's first three chapters were written in the authors' close cooperation.

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TURBINE AND ENGINE DESIGN

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AUTOMATED MARINE POWER INSTALLATIONS

Moscow SUDOVYYE AVTOMATIZIROVANNYYE ENERGETICHESKIYE USTANOVKI in Russian 1980 (signed to press 31 Mar 80) pp 34-40, 259-268, 321-322, 326-335

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/Text7 Chapter 4. Steam Cycles

9. Basic Cycle of a Steam Power Plant

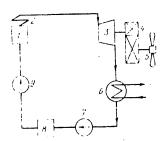


Figure 15. Diagram of steam power plant operating on a Rankine cycle.

In a steam power plant operating on a Rankine cycle (Figure 15), steam passes from steam boiler 1, which is fitted with steam superheater 2, into steam turbine 3, where it expands. The turbine operates on screw propeller 5 through reduction gear 4. The spent steam is directed into condenser 6, where it is cooled by water and condenses. The condensate is then pumped into holding tank 8 by condensate pump 7. From there the water is injected anew into the steam boiler.

Let us discuss the Rankine cycle in coordinates V-p (Figure 16a) and S-T (Figure 16b). The water initially receives heat at a constant pressure p₁, which for all practical purposes is realized by heating it until it vaporizes, after which the steam produced in the boiler is superheated. This process is shown by line bd in coordinates V-p and line abcd in coordinates S-T. In the latter case it is necessary to allow for the fact that the isobar of a liquid in coordinates S-T slopes slightly more than the lower boundary curve, although for practical calculations it can be assumed that they coincide.

After the heat is imparted, adiabatic expansion of the steam takes place (line de in both diagrams). After the steam expands to its final pressure p₂, it condenses (line ea in both diagrams). Finally, the feed pump again sends the water into the boiler (the pressure on it is increased), which is shown somewhat conventionally by constant-volume line ab in coordinates V-p.

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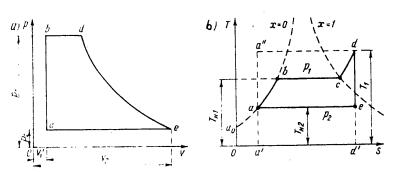


Figure 16. Graphs of Rankine cycle in volume-pressure and entropyabsolute temperature coordinates.

The thermal efficiency of the Rankine cycle can be derived from a discussion of it in coordinates S-T. The heat that is converted into work during the cycle is represented by area abcde. Expended heat is represented by area a'abcdd'. The thermal efficiency is the ratio of these areas:

$$\tau_{il} = \frac{abcde}{a'abcdd'}$$

Area abcde can be regarded as the difference between areas $0a_0$ bcd' and $0a_0$ aed'. The former measures the steam's enthalpy at point d and can be designated as i_1 ; the latter measures the enthalpy at point e and can be designated as i_2 . Area a'abcdd' equals the difference between areas $0a_0$ bcdd' and $0a_0$ aa'. The first area is i_1 , while the second represents the enthalpy of the water at point a. This value is designated as i_2 . Thus, the Rankine cycle's thermal efficiency is determined by the formula

$$\gamma_{il} = -\frac{i_1 - i_2}{i_1 - i_2} \tag{31}$$

The difference in enthalpies (thermal gradient) $i_1 - i_2$ during the adiabatic expansion of the steam is usually determined with an S-i diagram. For the same initial and final temperatures, the Rankine cycle's efficiency is lower than that of a Carnot cycle; this is obvious from a comparison of areas aa"de and abcde, which represent the amounts of heat used in the Carnot and Rankine cycles.

A study of formula (31) shows that the Rankine cycle's thermal efficiency increases as the steam's initial pressure and temperature do and as the final pressure decreases. It is necessary to allow for the fact that as the steam's initial pressure increases, there is an increase in the numerator of the Rankine cycle's efficiency formula (the value of the thermal gradient) only up to the value of an initial pressure on the order of 4 MPa. However, the cycle's efficiency also increases when there is a further increase in the steam's initial pressure. This is explained by the reduction at higher pressures (for the same superheating temperature) of the steam's initial enthalpy and the numerical value of the cycle's efficiency formula's denominator.

Steam with increased (pressure: 4-5 MPa, temperature: 723-773 K) and high (pressure: 8-12 MPa, temperature: 823-853 K) parameters is widely used to improve the degree of economy in marine steam power installations. At electric power stations in the

Soviet Union, the use of steam with supercritical parameters (pressure: 24 MPa; temperature: 873 K) has now been mastered for turbogenerators with an aggregate power of up to 1.2 million kW. Given the comparatively limited power of steam power installations, the use of steam with such high parameters cannot be justified economically.

10. Cycles With Repeated Superheating of Steam and the Regenerative Cycle

When there is an increase in the steam's initial pressure, there is also an increase in its moisture content at the end of expansion unless there is a simultaneous increase in the steam superheating temperature. An increase in the steam's moisture content at the end of expansion lowers the degree of economy of a steam turbine and causes blade erosion in the final stages. Thus, when the steam's initial pressure is increased, this makes it mandatory to increase its superheating temperature at the same time. However, when there is a significant increase in the steam's initial temperature, it is necessary to manufacture the circulating section's parts out of expensive heat-resistant alloys. Therefore, in high-pressure installations the steam's initial temperature is sometimes limited, but repeated superheating of it is used.

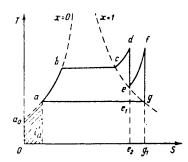


Figure 17. Graph of cycle with repeated superheating of the steam, in entropy-absolute temperature coordinates.

The cycle of a steam power installation operating with repeated (intermediate) superheating of the steam is shown in S-T coordinates in Figure 17. As in a normal Rankine cycle, the feed water (condensate), which has enthalpy ia, is heated to its boiling temperature in a steam boiler (line ab in the diagram). The water is then converted into dry, saturated steam (line bc) in the boiler, which steam is then superheated (line cd), with the enthalpy of the superheated steam reaching id. After this, the steam expands adiabatically in a high-pressure turbine until it reaches a state that is close to saturation (line de) and is sent into a second

steam superheater, where it is again superheated (line ef). It then expands adiabatically in a low-pressure turbine until it reaches its final pressure (line fg) and, with enthalpy i_g , condenses in a condenser (line ga).

Thus, a cycle with repeated superheating of the steam is represented by the figure abcdefg, the area of which corresponds to the amount of used (converted into work) heat. In the absence of repeated superheating, the unit would work according to the cycle represented by area abcde1, and the steam's moisture content at the end of expansion would be higher. The secondary superheating increases the amount of heat used by the value designated by area e1efg, but an additional expenditure of heat measured by the area e2efg1 is required. Designating the steam's enthalpy at points e and f as ie and if, let us derive the expression for the thermal efficiency of the cycle with secondary superheating of the steam:

$$\gamma_{t} = \frac{l_{1} - l_{p} + l_{1} - l_{2}}{l_{1} + (l_{1} - l_{c}) - l_{2}'}.$$
 (32)

When there is multiple superheating of the steam, line def approximates an isotherm, which increases the degree of economy of the cycle substantially (since it approximates a Carnot cycle). A single repeated superheating also produces some increase in thermal efficiency. Under real conditions, the degree of economy of a steam power installation with repeated steam superheating increases to an even greater degree because of the reduction in losses in the turbine as the result of the decrease in the steam's moisture content in the final stages. Besides this, repeated superheating increases the turbine blades' service life.

Installations with repeated steam superheating are very complicated because of the presence of a second steam superheater and two additional steam lines. As a result of the large volume steam in these lines, there is a sharp decrease in the maneuver qualities of such installations, so until recently repeated superheating was almost never used in marine steam power installations. In recent years, however, installations with repeated steam superheating have been used to a certain extent in seagoing ships. The series of "Krym"-type large-tonnage tankers, with steam power plants generating 30,000 hp, as well as all modern stationary power plants using steam with high initial parameters, have repeated steam superheating.

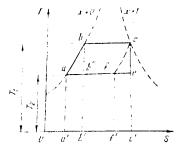


Figure 18. Graph of a regenerative cycle.

Cycles in which the return to the working fluid of part of the heat withdrawn from it is provided for are widely used in marine steam power installations. Such cycles are called regenerative (or heat-return).

In Figure 18, Rankine cycle abce (for the case of the use of dry, saturated steam) is depicted in S-T coordinates. The amount of heat withdrawn from the steam is indicated by area a acc. Let us assume that during the heat expansion process, part of the steam's heat is used, in an

infinitely large number of preheaters, to preheat the water fed into the steam boiler. This can be shown graphically by replacing adiabatic expansion line ce with the equidistant curve cf, which represents the preheating of the water.

The amount of heat withdrawn from the steam during its expansion is represented by area f'fcc'. It will be imparted to the water and can be represented by area a'abb', which is equal in size to area f'fcc'. Since areas abb" and fce are identical, area abcf of the cycle can be replaced by its equal area b"bce (a Carnot cycle). Consequently, in the ideal case and when working with saturated steam, the regenerative cycle's efficiency can reach that of a Carnot cycle. For all practical purposes such a cycle cannot be achieved, since the conditions for the continuous withdrawal of the expanding steam's heat for the purpose of preheating the water cannot be created.

In actuality, preheating of the feed water by steam taken from the steam turbines is used to realize a regenerative cycle in marine power installations. A simplified diagram of a steam installation operating with such a cycle is shown in Figure 19a. One special feature of this layout, in comparison with that shown in Figure 15, is the presence of feed water preheater 2, into which is directed steam taken from steam turbine 1 at some pressure p_{ot} during the expansion process. In the

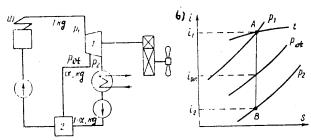


Figure 19. Diagram of theoretical steam expansion process in a steam power installation operating with a regenerative cycle.

simplest case, this steam is mixed with the feed water and can preheat it to temperature t_{ot} , which corresponds to the removed steam's pressure. The feeding into the steam boiler of water at a higher temperature reduces fuel consumption for the formation of steam, despite the slight increase in the total steam consumption in the steam turbine as the result of its intermediate removal to preheat the feed water.

If we use an S-i diagram (Figure 19b) to depict the process of adiabatic steam expansion in an installation operating with a regenerative cycle and a single intermediate removal of steam, it is easy to determine the values of the steam's initial and final enthalpies i_1 and i_2 and the removed steam's enthalpy i_{ot} . We will assume that steam with a mass of 1 kg enters the steam turbine, and after partial expansion it is bled off to preheat water with a mass of α kg. We can then formulate the following thermal balance equation for the preheater:

$$(1-\alpha)i_2^2+\alpha l_{\rm or}=i_{\rm or}^2,$$

where i'ot = enthalpy of the water preheated to temperature tot.

From this equation we determine the amount of steam removed:

$$\alpha = \frac{i_{\text{or}} - i_2}{i_{\text{or}} - i_2} \,. \tag{33}$$

The work done by 1 kg of steam in a regenerative cycle with a single intermediate bleeding of steam is the sum of the work done by α kg of steam, expanding from an initial pressure p_1 to the bleeding pressure p_0 , and $(1 - \alpha)$ kg of steam, expanding from an initial pressure p_1 to a final pressure p_2 . Thus, the work done by 1 kg of steam—or the amount of heat converted into work (in joules) is

$$l = \alpha (l_1 - l_{\text{or}}) + (1 - \alpha)(l_1 - l_2).$$

In this case the regenerative cycle's thermal efficiency is expressed by the formula

$$\eta_t = \frac{\frac{a(i_1 - i_{o1}) + (1 - a)(i_1 - i_2)}{i_1 - i'_{o1}}}{i_0 - i'_{o1}}.$$
(34)

For the same initial and final steam parameters, the thermal efficiency of a regenerative cycle is greater than that of a Rankine cycle, it being the case that it increases as the number of intermediate bleed-offs does (modern marine steam turbine power plants operate with three or four intermediate bleed-offs). The degree of economy of the regenerative cycle is explained by the return to the steam boiler

of the steam formation heat of that part of the steam produced in the boiler that is removed from the steam engine and used to preheat the feed water. At the same time the losses in the condenser are reduced, since a smaller amount of steam enters it when bleed-offs are used.

Examples

Example 1. Determine the thermal efficiency of a Rankine cycle when the initial steam pressure is 5 MPa, the initial temperature is 732 K and the final pressure is 0.005 MPa.

Using the S-i diagram, we determine the difference in enthalpies: $i_1 - i_2 = 3,320 - 2,080 = 1,240 \text{ kJ/kg}$. Using saturated steam tables, we find that $i_2 = 138 \text{ kJ/kg}$.

Then, according to formula (31),

$$\eta_t = \frac{l_1 - l_2}{l_1 - l_2'} = \frac{1240}{3320 - 138} = 0.39 \text{ (or } 39\%).$$

Example 2. Determine the efficiency of a regenerative cycle for the same initial and final conditions as in Example 1, providing that the steam is bled off at a pressure of 1 MPa.

According to the S-i diagram the removed steam's enthalpy is $i_{ot} = .2,760 \text{ kJ/kg}$. According to the saturated steam tables, $i_{ot}' = .763 \text{ kJ/kg}$.

According to formula (33), the amount of steam bled off is

$$a = \frac{i_{\text{or}} - i_2'}{i_{\text{or}} - i_2'} = \frac{763 - 138}{2760 - 138} = \frac{625}{2622} = 0,238 \text{ kg}.$$

According to formula (34), the thermal efficiency is

$$\frac{a_{l_1} - a_{l_1} - a_{l_1} + (1 - a_{l_1}) + (1 - a_{l_1}) + (1 - a_{l_2})}{i_1 - i_{01}} = \frac{0,238 (3320 - 2760) + 0,762 (3320 - 2080)}{3320 - 763} = \frac{0,238 \cdot 560 + 0,762 \cdot 1240}{2557} = 0,42 \text{ (or, 42\%)}.$$

The increase in thermal efficiency gained by changing over to a regenerative cycle, in comparison with the thermal efficiency achieved in Example 1, is

$$\frac{42-39}{30}$$
 100 = 7.7%.

Heat is drawn from the core by means of a cooling substance called the heat-transfer agent -- water, organic liquids, liquid metals and their alloys (potassium, sodium, bismuth and so on), gasses (helium, nitrogen, carbon dioxide). Only water is used as the heat-transfer agent in modern marine reactors.

When a reactor is in a steady-state operating mode, its core is in the critical state. The intensity of the neutron flux and the number of fissionings per unit of time are constant values in this case. In order to change the liberation of heat in the reactor, it is necessary to regulate the intensity of the neutron flux and the number of fissionings per unit of time; that is, to change the speed of the chain reaction. A regulation system does this.

The basis of the regulation system is rods containing substances that are heavy absorbers of neutrons (boron carbide, cadmium). The position of the rods in the reactor is usually regulated by a special automatic device. In order to increase heat liberation, the rods are withdrawn from the reactor, while to reduce it they are moved into it.

Nuclear fuel is consumed (burned up) in the process of reactor operation. When the fuel is burned up to a certain degree, it is necessary to replace the fuel elements. The period between these changes is called the reactor run.

When a reactor is in operation, fragments and fission products having a great capacity for absorbing neutrons are obtained. Xenon (Xe¹³⁵) is the strongest absorber of neutrons. As a result, there arises a phenomenon known as "poisoning" of the reactor. This phenomenon manifests itself most strongly after a reactor that has been operating at high power is stopped suddenly. In order to start a "poisoned" reactor, the presence and release of excess core reactive capacity or a long time to reduce the xenon concentration is required.

The regulation system must insure not only the required generation of heat in the reactor, but must also be able to release the reactor's excess power in case it is "poisoned." Besides this, this system or a special protection system must instantaneously stop the chain reaction if an emergency situation arises.

During nuclear reactions, about 80 percent of the energy is converted into heat, while the other 20 percent is in the form of α -, β - and γ -radiation. No special danger is posed by α - and β -radiation, since they have an insignificant penetrating capability. However, γ -radiation and neutron radiation have a great penetrating capability and cause secondary radiation in many materials. When acted upon by such radiation, the human body is beset by serious illnesses, so a nuclear power plant must have so-called biological shielding, for which metals, water and concrete (in stationary power plants) are used. Biological shielding facilities are always quite large and heavy.

68. Layouts and Basic Characteristics of Nuclear Power Plants

The schematic diagrams of nuclear power plants depend on the type of coolant and the type of engine or engines utilizing the thermal energy. Nuclear power plant layouts can be either single- or double-circuit.

A single-circuit layout of a nuclear power plant using water as both the coolant and the heat-transfer agent is shown in Figure 143a. By ccoling the fuel elements

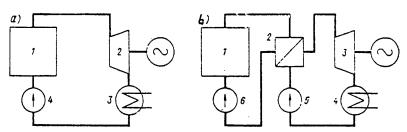


Figure 143. Diagrams of nuclear power plants.

of reactor 1, water is converted into steam that expands in turbine 2 and is then sent into condenser 3, where it is converted back into water. Pump 4 feeds the water back into the reactor.

The advantage of a single-circuit system is its simplicity and the possibility of using steam in the turbine at a pressure of up to 10 MPa and a temperature of up to 550°C, which insures high economy of operation of the steam section of the nuclear power plant. In this case, however, the turbine, the condenser and the mechanisms supporting them must be behind biological shielding, since the steam is dangerously radioactive. Therefore, single-circuit layouts have not yet been used for power plants.

At the present time the overwhelming majority of nuclear power plants (including marine ones) are realized according to the two-circuit plan with water as the reactor coolant and the engine's working fluid (Figure 143b). Water leaves reactor 1 at a pressure of 6-15 MPa and is sent into heat exchange unit 2, which is called the steam generator. Because of the heat of the water in the first circuit, steam that is no longer radioactive is produced in the steam generator. Pump 6 feeds the water in the first circuit back into the reactor. This pump and the steam generator are behind biological shielding. The steam from the steam generator expands in turbine 3 and is then converted back into water in condenser 4. Pump 5 feeds this water back into the steam generator.

The advantage of this setup is that the steam turbine, the condenser and their supporting mechanisms are accessible for maintenance. However, the pressure in the second circuit is always considerably lower than in the first because of the necessity of providing a temperature differential in the steam generator. This pressure is most frequently on the order of 3 MPa. For this same reason, the superheating temperature of the steam in the second circuit does not exceed 300°C (573 K), which is another defect in this setup. As a result, the efficiency of the power plant's steam section cannot be high.

In order to improve the parameters of the steam in the second circuit, it was suggested that several liquids that are organic compounds be used as the moderator and the heat-transfer agent: diphenyl, orthotriphenyl, metatriphenyl, paratriphenyl and mixtures of these.

Organic liquid are explosion— and fireproof and nonpoisonous, are good neutron moderators, are not very chemically active with respect to metals, are thermally stable up to temperatures on the order of 673 K, have a high boiling temperature at atmospheric pressure (about 533 K), and are not very active when acted upon by nuclear radiation. All of this makes it possible to insure improved economy of

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Chapter 19. Nuclear Power Plants

67. Physical Principles of the Operation of Nuclear Reactors

The reserves of fuel of organic origin are limited, so the question of other energy sources has arisen. The discovery of the possibility of obtaining thermal energy as the result of the chain-reaction fissioning of the nuclei of such elements as uranium (and several others) was an extremely important one. The energy reserves in the uranium available on Earth are tens of times greater than the energy of all the world's reserves of organic fuel. The energy generated during the full utilization of 1 kg of uranium is approximately equal to that obtained by burning 1,400 t of fuel oil.

The obtaining of thermal energy by splitting the nuclei of fissionable elements takes place in devices called nuclear reactors. Enriched uranium is used as the nuclear fuel for modern reactors used for energy purposes. In natural uranium the content of the easily fissionable isotope ${\tt U}^{235}$ is about 0.7 percent, while the other 99.3 percent is the practically unfissionable isotope ${\tt U}^{238}$. Artificially enriched uranium with a ${\tt U}^{235}$ isotope content of 3-5 percent is normally used in reactors.

In reactors used for energy purposes, the process of splitting uranium nuclei with neutrons is realized. In connection with this, a U²³⁵ nucleus is split into two fragments with the same charge and approximately the same weight and charge that, being repelled by each other, move apart at extremely high speeds. When the fragments collide with the atoms of the medium in which the nuclear fission occurs, their kinetic energy is converted to heat. In each case of fissioning of uranium nuclei, for each absorbed neutron an average of 2.5 neutrons fly away and, under certain conditions, themselves cause other U²³⁵ nuclei to be split. This is the essence of the chain-reaction fissioning of nuclear fuel. Such a reaction can be steady state, dying out, or growing. Correspondingly, the reactor's status is critical, subcritical, or supercritical. The chain reaction takes place in that part of the reactor called the core, where the fissioning material is.

Reactors in which the neutrons' velocity is moderated to the velocity of their thermal motion are used for energy purposes. They are known as thermal neutron reactors. In order to insure a chain reaction in them it is necessary to use enriched uranium and to introduce into the core a special substance known as the neutron moderator. Water (H_2O) , heavy water (D_2O) , beryllium and graphite can be used as the moderator. Although water is not as strong a moderator as the other materials, it may also be used simultaneously as a heat-carrying agent.

Reactors are categorized as homogenous and heterogeneous, depending on the type of core. In homogeneous reactors the nuclear fuel and the moderator are a homogeneous mass. In heterogeneous reactors the nuclear fuel is arranged in the moderator in the form of rods or plates that in this case are called fuel elements. Right now, heterogeneous reactors are the only type used in nuclear marine power plants [SEU].

A reactor's core must be surrounded by a reflector that insures a decrease in neutron loss and, consequently, contributes to a decrease in the core's dimensions. The reflector also facilitates equalization of the neutron flux in the core. The same substances that are used as moderators are used as reflectors (in marine reactors it is usually water).

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operation and reliability of nuclear SEU's while maintaining a low pressure in the first circuit.

However, organic liquids also have flaws. When acted upon by heat and radiation they tend to break down, which requires systematic purification and level maintenance of the heat-transfer agent in the first circuit. The low thermal capacity and thermal conductivity of organic liquids requires an increase in the heat-transfer agent consumption rate and enlarged surfaces in the heat exchange units.

The question of the feasibility of using organic liquids as the moderator in nuclear SEU's needs to be tested under regular operating conditions.

69. Utilization and Facilities for the Automation of Nuclear SEU's

Almost from the very beginning of the construction of atomic (nuclear) electric power stations, work was begun on the use of nuclear power plants for transport ships. This is explained by a number of circumstances.

First of all, it should be mentioned here that a marine nuclear power plant makes it possible for a ship to sail for a practically unlimited length of time without replenishing its fuel supply. The daily consumption of nuclear fuel in transport ships is only tens of grams. The fuel elements in the reactors can be changed once every 2-3 years.

The useful cargo-carrying capacity of ships with nuclear power plants can be increased in comparison with ships having standard power plants and the same hull dimensions. Although the weight of nuclear power plants is quite high because of the high weight of the biological shielding, an atomic-powered ship does not carry fuel reserves. Therefore, the weight of a nuclear power plant is always less than that of a standard power plant of the same power along with its fuel reserves.

The use of nuclear power plants can be regarded as an economically profitable way of increasing the speed of transport ships. For standard power plants, an increase in a ship's speed entails not only an increase in fuel consumption, but also a significant reduction in the useful cargo-carrying capacity because of the increase in fuel reserves.

Finally, one exceptionally important advantage of nuclear SEU's is the absence of a need for air in order to function. Thus, the problem of the extensive use of underwater transport ships (primarily tankers) can be solved. It is a well known fact that less main engine power is required to provide high speeds during underwater sailing. Underwater vessels with nuclear power plants can also sail beneath the ice in the Arctic basin.

The reactor in the ship "Otto Gan" (a cross-section of which is shown in Figure 144) can serve as an example of the layout of a marine nuclear reactor. The reactor is designed for a steam-turbine power plant producing 7,400 kW. Water is used as the moderator and the heat-transfer agent. A pressure of 6.3 MPa is maintained in the first circuit. In the second circuit, 64 t/h of steam is produced at a pressure of 3.1 MPa and a temperature of 546 K.

The reactor vessel consists of cylinder 8, the bottom and cover 3 of which have a hemispherical shape. Connecting pipes for supplying feed water and discharging

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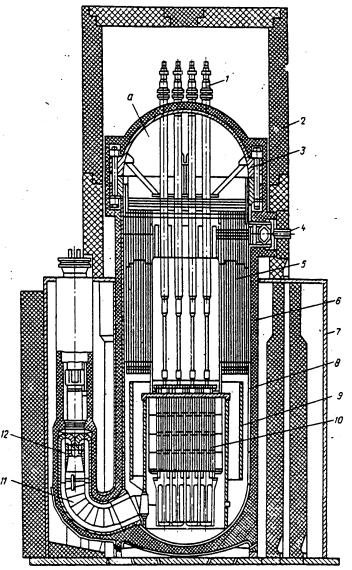


Figure 144. Nuclear reactor.

steam are welded to the cylindrical part of the vessel. Connecting pipes for the circulation pumps are welded to the bottom. The cover has 12 openings for the regulating rod drive.

Core 10 is 1,150 mm in diameter and 1,120 mm tall. It contains 16 cells with rods made of uranium oxide that is enriched with respect to U^{235} . The total amount of uranium oxide (UO₂) in the core is 2.95 t, which insures the reactor's operation for 500 days.

In the center of each cell with a square cross-section (12 of the 16) there is a control rod made of tubes containing boron carbide.

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The rods are moved automatically or by manual control by means of drive 1, which is mounted on the vessel's cover. The reactor's core is surrounded by thermal screen 9. The first circuit's circulation pumps 12 feed water into the core through connecting pipes 11.

Steam generator 5 consists of three independent sections formed by 54 spiral tubes. Its total heating surface is 465 m^2 . The feed water is supplied to the steam generator through connecting pipes 4. The steam generator is fitted with heat insulation 6.

The reactor under discussion has a unitized design, since the core, the steam generator and the first circuit's three circulation pumps are in common container 7. The entire reactor is surrounded by biological shielding shell 2.

During operation, a free water level is maintained in the reactor vessel. The pressurized steam in the first circuit occupies the space above it. This steam level a fulfills the role of pressure stabilizer.

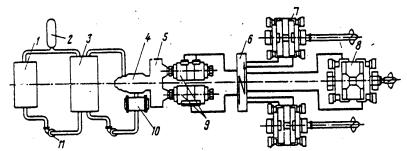


Figure 145. Schematic diagram of the power plant in the icebreaker "Lenin."

The world's first, most powerful and technical perfect nuclear power plant installed in a merchant marine ship was the power plant in the atomic-powered icebreaker "Lenin" (Figure 145). The total power of the main power plant, on the flanges of the 4 turbines, is 32,600 kW.

Reactor 1 is equipped with pressure stabilizers 2 in the first circuit. Ordinary water is used as the moderator and heat-transfer agent. The first circuit's water enters steam generators 3. Water circulation in the first circuit is provided by electric pumps 11. In the steam generators, second-circuit steam is produced at the rate of 360 t/h, at a pressure of 2.9 MPa and a temperature of 583 K. The steam then moves into four steam turbines 4. The used steam is sent into condensers 10 and the condensate is used again to feed the steam generators. Each turbogenerator drives two electric generators 9, which generate direct current at 600 V, through reduction gear 5.

Through GRShch 6, electric energy is fed to main electric propulsion motor 8 and two lateral engines 7. The electric propulsion motors operate directly on the screw propellers' shafts. The central motor's power is $14,500~\mathrm{kW}$, while the lateral ones generate $7,600~\mathrm{kW}$ each.

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The fore and aft turbine rooms each contain two main turbogenerators that each generate 8,100 kW. The turbines consist of an active pressure-regulating stage and 15 reactive stages.

On the icebreaker there are also five auxiliary turbogenerators, each of which has a capacity of 1,000 kW. They produce three-phase alternating current at 400 V for the operation of all the auxiliary mechanisms. There is also a diesel generator with the same capacity.

In order to provide the ship with steam while at anchor when the reactors are not operating, there are two auxiliary water-tube steam boilers with a total steam productivity of 10 t/h at a pressure of 2.9 MPa.

The extended and successful experiment in operating the nuclear power plant in the icebreaker "Lenin" has demonstrated the correctness of the principles on which its construction was based. This has made it possible to realize even more powerful power plants for the monotypical icebreakers "Arktika" and "Sibir'," which each generate 56,000 kW.

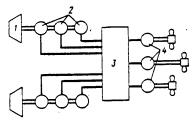


Figure 146. Diagram of power plant in icebreakers "Arktika" and "Sibir'."

The steam-producing unit on the icebreakers "Arktika" and "Sibir'," which was realized according to the plan of the unit on the "Lenin," differs from it only in steam productivity. In all other respects, however, the power plants in these icebreakers differ significantly. A simplified diagram of the power plants in the "Arktika" and "Sibir'" is shown in Figure 146

In the steam generators' second circuit, steam is produced at a pressure (before the outlet to the turbines) of 3 MPa and a temperature of 573 K. The two turbines 1 each have a capacity of 27,800 kW at 3,500 r/min. The single-casing double-flow turbines have anactive regulating radial stage and 15 reactive stages in each flow. The pressure in the condenser is 0.007 MPa.

Each turbine is connected directly to three alternating-current generators 2, which each produce 9,000 kW at 110-125 Hz and 780 V. By means of silicon rectifiers 3 the alternating current is converted into direct current at 1,000 V. Three two-armature main propulsion motors 4 operate on the direct current. Each main propulsion motor operates its own fixed-pitch screw. All of the electric motors have the same power--17,600/16,200 kW at 130/185 r/min.

The icebreaker's electricity requirements are filled by five 2,000-kW turbogenerators. In addition to them, there is a 1,000-kW reserve diesel generator and two 200-kW emergency diesel generators. In order to fill the requirements for steam for heating and domestic needs when the steam-producing unit is not operating, there are two automated auxiliary low-pressure water-tube boilers that operate on liquid fuel.

On the icebreaker there are systems for the automatic control and monitoring of the power plant. These systems provide the following:

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freeing of personnel from constant watches in the power plant area; automatic regulation of the processes occurring in the power plant, including emergency situations; operational, centralized monitoring of parameters and remote control of the equipment;

signaling and automatic recording of the departure of monitored parameters from the established norms;

high reliability in the automation facilities.

An integrated system for automating the power plant was developed for the icebreakers "Arktika" and "Sibir'." It contains the following systems: automatic regulation, control and protection of the steam part of the power plant: reactor control and protection; collection, processing and presentation of information; remote and automated control of onboard systems; automation of the electric part of the power plant.

The automation systems are realized with the use of elements and circuits that have already been tested operationally and new ones that are further improvements and that insure the high reliability of the systems. The center for information collection and the control of the equipment for the icebreaker's entire power plant is the TsPU. Registration of the parameters and deviations from their given values is done with a special digital printing unit.

The cargo and passenger ship "Savannah," with a nuclear power plant generating 16,000 kW, was built in the United States. It was not operated for long and at the present time is laid up. In the FRG's merchant fleet there is a cargo ship (an ore carrier) with a 7,400-kW nuclear power plant. The experimental ship "Mutsu," with a 7,400-kW nuclear power plant, has been built in Japan. However, serious flaws were discovered in the power plant during the first voyages and the ship is being refitted. The Italian ship "Enrico Fermi" will be 175 m long and 22.5 m wide. Its nuclear power plant will generate 16,000 kW and the vessel will cruise at 20 mi/h. When fully loaded, its displacement will be 18,000 t.

At the present time, a great deal of experience has been amassed in the operation of nuclear power plants of both the stationary and marine types. This experience indicates that they are both highly reliable and safe. The improvement and simplification of the technology for producing nuclear fuel will result in a continuing reduction in its cost. When the construction cost of nuclear power plants themselves is reduced, we can expect that in the near future ships with such power plants will become much more common.

Section 6. Marine Auxiliary Mechanisms. Special Features of the Operation of Marine Power Installations

Chapter 22. Cooling and Evaporating Installations

82. Automation of Refrigeration Units

All modern marine refrigerating units, whether intended for cooling compartments and cargoes and preserving perishable goods or for air conditioning, are equipped with automation facilities. The extent of the automated processes depends on the purpose of the installation, its special technical features and the cooling method used.

The basic parameter for regulating a refrigerating unit is its cold productivity. For the automatic maintenance of the temperature of cooled areas within given limits, a balance must be maintained between the flow of heat into the area and the refrigerating unit's cold productivity. Since the magnitude of the heat flow is subject to change, the unit's cold productivity must also change within the appropriate limits.

The best method for regulating cold productivity is a smooth change in the compressor's rate of revolution. However, the complexity of regulating the rate of revolution makes it impossible to use this method of cold productivity regulation extensively.

In marine refrigerating installations, the most widely used method is positional regulation of the cold productivity by starting and stopping the compressor. In this case the temperature in the area being cooled is maintained with certain given limits. The difference between the temperatures at which the compressor starts and stops is called the temperature differential. Its value must usually not exceed 2°C.

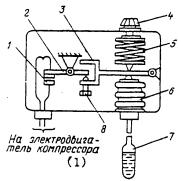


Figure 182. Diagram of action of two-position system for regulating a refrigerating installation.

Key: 1. To the compressor's electric the electric motor stops.

In a two-positional system for regulating cold productivity (Figure 182), the sensitive element is thermocylinder 7, which is located in the area being cooled and is connected by a pipe to bellows 6. The bellows is compressed by spring 5, the tension on which is regulated with controller 4. When the temperature in the cooled area increases, evaporation of the volatile liquid in thermocylinder 7 intensifies and bellows 6 overcomes the tension on spring 5, lever 3 moves rocker arm 2 and closes contact 1, which turns on the compressor's electric motor. When the temperature drops, the process takes place in the reverse order, contact 1 opens, and

The temperature differential is adjusted by means of screw 8. Tightening of the screw reduces the temperature differential. The temperature in the cooled area is set with controller 4, by changing the tension on the spring that acts on the bellows.

In powerful refrigerating installations, the amount of automation can be increased considerably. For instance, there can be automatic regulation of the level of the cooling agent in the condensers and evaporators, the cooling agent's superheating temperature, and the pressure in the condenser. The removal of air from the installation can also be automated.

Chapter 23. Special Features of the Operation of Shipboard Power Installations

84. Operating Qualities of Different Types of SEU's

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The technical operating qualities of different types of SEU's are evaluated according to several indicators, the most important of which are specific fuel consumption rate, weight of the installation, aggregate power, reliability, maneuvering qualities and duration of the period between repairs.

When evaluating the specific fuel consumption rate, it is necessary to allow for it not for the main engine alone, but for the entire SEU; that is, to keep in mind the operation of the auxiliary mechanisms and other fuel requirements. The total hourly fuel consumption rate should be divided by the main engine's rated power. The specific fuel consumption rate for the entire installation depends to a considerable degree on the type of ship, since it is precisely this that affects the auxiliary engines' power and fuel consumption for heating and domestic needs. For example, for the same type of main engine the specific fuel consumption rate for the entire installation is considerably higher in a passenger ship than in a cargo vessel; for diesel power plants it also depends to a considerable degree on the degree of utilization of the heat of the exhaust gasses and the cooling water.

Below are some data on the average specific fuel consumption rate for modern SEU's (in grams per kilowatt-hour):

Installation Spec	ific Fuel	Consumption			
Steam turbine		260-310			
Diesel with direct drive and power up to 8,800 kW.		220-240			
Diesel with direct drive and power above 8,800 kW.					
Geared diesel					
Diesel electric					
Gas turbine					

The lowest specific fuel consumption rate is provided by a power diesel power plant with direct drive (low-revolution engine) that has a system for the thorough utilization of waste heat (200-210 g/kWh). The specific fuel consumption rate of steam-turbine power plants that is acceptable under modern conditions (260-270 g/kWh) can be achieved only if they are quite complicated, with high initial steam parameters (8-10 MPa, 773-823 K) and high power (22,200-37,500 kW). Gas-turbine power plants that utilize the exhaust gasses' heat in the steam stage can have a specific fuel consumption rate that approaches its value in diesel power plants. However, these installations are quite complicated. The specific fuel consumption rate in gas-turbine power plants realized from simple plans is still quite high, but should decrease as the installations are improved.

Reducing the weight of a power plant usually lowers its cost and increases a ship's pure cargo-carrying capacity. Below are the average weights of power plants of different types.

Instal:												<u>/sic/</u>
Steam turbine				•								40-80
Diesel with direct drive											. (50-100
Geared diesel												30-40
Gas turbine												15-20

As far as weight is concerned, gas-turbine power plants are unarguably in first place.

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At the present time, the greatest main turbogear assembly [GTZA] power in transport ships is 52,000 kW. The highest-powered low-revolution diesel engines are approaching 37,000 kW, while for medium-revolution diesels the figure is 13,000 kW; gas-turbine installation power has reached 18,500 kW and will undoubtedly increase.

An SEU's maneuvering qualities are of great importance for operating a ship. They can be evaluated by the following indicators: duration of preparation for operation of steam-turbine power plants—3-5 h; diesel engines—0.5-1 h; gas-turbine units [GTU]—no more than 0.5 h; amount of time it takes to reverse a GTZA—10-20 s; diesel—no more than 10-12 s; a GTU with a variable—pitch screw [VRSh]—even faster. It should, however, be mentioned that regardless of the type of power plant, the ship's speed has a strong influence on the amount of time it takes to reverse an engine (as the speed increases, so does the amount of time it takes to achieve reverse). This is explained by the fact that after the steam is shut down in a GTZA or the fuel pumps of a diesel engine are turned off, the screw propeller operates in the hydraulic turbine mode and develops considerable power when a ship is moving at a high speed. Only after the ship's speed is reduced can the torque created by the screw propeller be overcome and the engine started in the opposite direction.

During maneuvers, the possibility of maintaining a low revolution rate with the main engine is of great value. A GTZA's minimum stable rate of revolution is 10-12 percent of the rated level. For diesel engines this figure is higher and reaches 25 and even 30 percent, which has a deleterious effect on a ship's maneuvering qualities. In view of the small amount of experience in operating them, this indicator has not yet been firmly established for GTU's.

Steam and gas turbines, as well as internal combustion engines [DVS], do not allow a rapid transition from low to high speed. This limitation on maneuverability is related to the danger of the appearance of thermal stresses in critical parts. Both steam turbines and diesels do not allow extended, significant overloads: the allowable power overload is only 10 percent above the rated power for a period of up to 1 h.

Trunk DVS's and crosshead ones with two-sided parallels can operate in the reverse mode for an unlimited period of time at a power that is right up to the rated level. Steam turbines can operate in the reverse mode for only a limited period of time because of heating of the forward-running stages; at the same time, the reverse-running stages' power is usually only 40 percent of the forward-running stages'. A considerable improvement in the maneuvering qualities of steam-turbine power plants is achieved by the use of a VRSh.

When screw VFSh's are used, the maneuvering qualities of diesel power plants are better than those of steam-turbine power plants. The use of a VRSh equalizes these qualities to a considerable extent. The maneuvering qualities of a GTU are as good as those of diesel power plants. Of course, the best maneuvering qualities are achieved in power plants with electromotion; the problem of remote control is also simplest to solve when electromotion is used.

For modern low-revolution diesel engines and steam-turbine power plants, the periods between repair (motor life) are practically identical and have reached 100,000 h; for medium-revolution diesels it is 40,000 h; for the high-speed diesels used in seagoing ships with electromotion, it drops to 20,000 h. In principle, GTU's can have a motor life approaching that of steam-turbine or diesel power plants.

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85. Effect of Changes in Operating Conditions on the Operating Mode of SEU's, Fuel Consumption and Transportation Costs

A marine main engine is connected either directly or through a transmission to a screw propeller, so its operating mode and the operating mode of the entire power plant always depends on the screw propeller's operating conditions. In any steady-state mode, the power developed by the main engine — after subtracting the losses in the transmission (if there is one), the shaft line and the propeller — is used to overcome the resistances to the ship's motion. If the amount of working fluid entering the engine changes, there is also a change in the amount of power developed by it. This will cause a change in the rate of revolution of the engine and the propeller, which leads to a change in the ship's speed and, consequently, the establishment of a new state of equilibrium between the engine's power and the resistance to the ship's movement.

Given a constant ship's draft, an unchanged state of the sea and the same wind force and direction, there exists an approximately direct proportionality between the engine's rate of revolution and the ship's speed; that is,

$$\frac{v_1}{v_2} = \frac{n_1}{n_2} \,. \tag{100}$$

When the propeller is completely submerged, between the main engine's power N and the ship's speed v or the rate of revolution n there exists, as is well known, an approximately cubic relationship

$$\frac{N_1}{N_2} = \left(\frac{v_1}{v_2}\right)^3 = \left(\frac{n_1}{n_2}\right)^3. \tag{101}$$

For calculations that do not require high accuracy, fuel consumption can be assumed to be proportional to the main engine's power, so between hourly fuel consumption B in a power plant and the ship's speed or the engine's revolution rate we can also assume a cubic relationship

$$\frac{B_1}{B_2} = \left(\frac{v_1}{v_2}\right)^3 = \left(\frac{n_1}{n_2}\right)^3. \tag{102}$$

It should be mentioned here that for some types of ship, at reduced speeds the exponent in formulas (101) and (102) is approximately 2.5.

It is obvious that the total fuel consumption for a passage of \mathcal{T} hours will be $G = B\mathcal{T}$ kilograms. If a ship makes a passage of the same length at different speeds and, consequently, a different duration, the corresponding total fuel consumptions will be $G_1 = B_1 \mathcal{T}_1$ and $G_2 = B_2 \mathcal{T}_2$. However, the duration of the passages will be inversely proportional to the speed:

$$\frac{\tau_1}{\tau_2} = \frac{v_2}{v_1},$$

so fuel consumption on a passage with different speeds, allowing for formula (102), will be

$$\frac{G_1}{G_2} = \frac{B_1 \tau_1}{B_2 \tau_2} = \frac{v_1^3}{v_2^3} \frac{v_2}{v_1}, \text{ or } \frac{G_1}{G_2} = \left(\frac{v_1}{v_2}\right)^2.$$
 (103)

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Consequently, the fuel consumption rates for the entire passage at different speeds are proportional to the squares of these speeds. Formulas (100), (101) and (102) enable us to make the calculations that are constantly encountered in the practice of operating ships in the maritime fleet.

Under conditions of daily operation, a ship is operated with different loads and, consequently, with different drafts; that is, the resistance to its motion is different. For a constant speed, this requires a change in the main engine's power. The resistance to motion also depends on the hydrometeorological conditions and other factors (towing of non-self-propelled objects, sailing in shallow water or ice, and so on). All of these circumstances affect the propeller characteristic, which was discussed earlier.

The travel characteristic gives a quite clear picture of the interaction of the main engine, the screw propeller and the ship's hull under various sailing conditions. It represents the relationship among the main engine's power, the shaft's rate of revolution and the ship's speed in steady-state modes. The travel characteristic is constructed on the basis of calculations using the results of testing of ships in a given series.

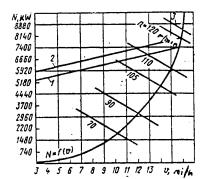


Figure 184. Travel characteristic.

The travel characteristic shown in Figure 184 shows the dependence of the main engine's power on the ship's speed when fully loaded for different constant rates of screw propeller revolution. For each given rate of revolution, this relationship can be assumed to be linear. On the characteristic it is possible to plot maximum power boundary curves and the screw characteristics for different sailing conditions. For instance, on the characteristic shown in Figure 184, the limitations on the magnitude of the torsional moment on the main engine's shaft at rated (line

1) and maximum (line 2) overload power are shown, along with the limitation on maximum power (line 3).

The use of the travel characteristic makes it possible to establish the power plant's mode for different ship operation conditions. A power plant's specific fuel consumption rate (per kilowatt-hour) depends on the power developed by the main engine, and for some consumption rate optimum values are achieved. A ship operating mode corresponding to the lowest specific fuel consumption rate is usually the best one for SEU operation. However, this mode normally corresponds to less than full main engine power. The operation of a power plant in the lowest specific fuel consumption mode leads to a reduction in a ship's speed, which is irrational from the viewpoint of operating it, since it entails a reduction in the turnover rate and, consequently, the cargo capacity and the speed with which carges are delivered.

In the final account, the basic fuel utilization indicator is fuel consumption per unit of transported goods (the ton-mile), which is always lower when there is an increased amount of cargo transported in a shorter period of time.

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Thus, the question of the choice of the rational SEU mode is always solved as a function of the set of all ship operating conditions.

The amount of fuel expended depends on the work done not only by the engineering staff, but also that done by the deck crew. First of all, the fuel consumption for a voyage and, in the final account, for mavigation is reduced when the time spent at anchor is reduced. Consequently, the correct organization of cargo operations, resulting in their acceleration, insures a reduction in fuel consumption per unit of transported goods.

The nature of a ship's cargo and its correct fore-and-aft trimming affects a power plant's operating mode; the quality of the helmsmen's work also has a noticeable affect on fuel utilization. A ship's actual path is always a broken line, since some yawing is inevitable; the distance traveled, however, is figured on a straight line. Therefore, the more accurately the helmsman holds the ship on course, the less the ship's actual path will deviate from the straight line and the lower the fuel consumption per mile. In connection with this, fuel utilization improves when an autopilot is used. This is explained by the fact that automatic operation of the rudder insures less yawing on the part of the ship.

Finally, the correct choice of the ship's path affects fuel utilization. It is a well known fact that the shortest ship's path is not always the most advantageous one. The use of following currents, steering away from regions with stormy weather and so on are of importance in reducing fuel consumption.

In connection with the increase in the speed of modern seagoing ships, at the present time there has been a significant increase in SEU power and fuel consumption. At the same time, there has been an increase in world prices for fuel. The share of the fuel component in the cost of marine transportation is 25-30 percent, and for certain types of ships it reaches 40 percent. Thus, fuel utilization is an important factor in the cost of shipments, and reducing fuel consumption is the goal of a seagoing ship's entire crew.

In addition to reducing expenditures for fuel and lubricating materials, transportation costs are also affected by the amount of time consumed in repairing a ship's power equipment. This time is reduced when there is careful maintenance of the mechanisms and improvements in their reliability. On the whole, good organization of the crew's work and conscientious fulfillment of his obligations by each member of the crew can insure the achievement of the highest ship operation indicators.

86. Principles of Normalization of Fuel Consumption in SEU's

The correct establishment of SEU fuel consumption norms is of great importance in organizing SEU maintenance, using the engines' theoretical power, and achieving the best fuel utilization indicators. Fuel consumption depends to a large degree on the power actually developed by the power plant, as well as the ship's speed.

Several standards have been established for normalizing fuel consumption in the transport fleet:

specific fuel consumption per unit of indicated power, in kilograms per indicated horsepower-hour;

fuel consumption per ship-hour, in kilograms per hour; fuel consumption is given in

weights of a conventional fuel; that is, a fuel having a combustion heat lower than 7,000 kcal/kg; any fuel is converted into an amount of conventional fuel according to its actual combustion heat;

actual power -- main engine power, developed at full, half and low speed, figured as the weighted average for a period of a month;

cruising power -- the rated power at which an engine can be operated without any time limitations;

the given main engine power recommended by the producer plant (or established by the steamship line) for purposes of increasing the engine's service life and achieving the lowest specific fuel consumption rate for protracted operation for a given ship. The main engines' power is figured in kilowatts;

average speed, defined as the quotient of the division of the logged distance covered on a voyage, in miles, by the ship's travel time, excluding maneuver time and time spent traveling at low speed (half, low and extreme low).

When calculating the actual speed from the distance covered and the ship's travel time, the following periods are excluded: sailing in ice, fog and under storm conditions; passage through narrows, canals and uncharted channels; other cases of travel at reduced speed, as provided for in the rules of navigation.

For calculating and analyzing fuel utilization, the steamship line's heat engineering department gives each ship the following norms:

power, in kilowatts -- given (average) N_g , when carrying cargo N_c , when in ballast N_c :

speed, in miles per hour -- given (average) v_g , when carrying cargo v_c , when in ballast v_b ;

conventional fuel consumption race — at full speed (specific) b_f (in kilograms per indicated horsepower-hour), at medium speed B_m (in kilograms per hour), at slow speed B_s (in kilograms per hour), when maneuvering B_{mn} (in kilograms per hour), at anchor with cargo operations B_c (in kilograms per hour), at anchor without cargo operations B_{nc} (in kilograms per hour), at anchor and ready to sail B_r (in kilograms per hour).

Calculation and analysis of the fulfillment of the assigned fuel consumption norms are done on the basis of entries in the engineer's log and the engineer reports. The latter contains all the materials that explain special sailing conditions (sailing in ice, in stormy weather and so on).

The actual weighted-average power is determined from the results of indexing the engine when carrying cargo and when in ballast. When indexing is impossible (for turbine-powered ships, steamships with high-speed engines), power is determined according to the screw characteristic or theoretically.

In order to determine the actual power when a ship is carrying cargo, we should know the average rate of revolution when loaded (n_c) , on the basis of data in the engineer's log, and the revolution rate when the indicator diagrams under load (n_c) are read. The actual power when carrying cargo will be

$$N_{c} = N_{c1} \left(\frac{n_{c}}{n_{c1}}\right)^{3}, \qquad (104)$$

where N_{ci} = the power obtained by indexing.

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When a ship is sailing in ballast, if engine indexing yields power $N_{\rm bi}$ at a rate of revolution $n_{\rm bi}$, the actual power in ballast for an average revolution rate of $n_{\rm b}$ will be

$$N_{6} = N_{bi} \left(\frac{n_{b}}{n_{bi}} \right)^{3}. \tag{105}$$

If, during a reporting period, the amount of time a ship carried cargo was to hours and the time spend in ballast was to hours, the engine's actual average-weighted power will be

$$N_{a} = \frac{N_{c} t_{c} + N_{b} t_{b}}{t_{c} + t_{b}} . \tag{106}$$

If the specific fuel consumption rate norm for full speed is bf (in kilograms per indicatoed horsepower-hour), the fuel consumption norm for full speed, given the actual power, will be (in kilograms per hour)

$$B_{\mathbf{f}} = b_{\mathbf{f}} \cdot N_{\mathbf{a}}. \tag{107}$$

Taking into consideration the travel time and the time spent at anchor with and without cargo operations, it is easy to calculate the fuel consumption according to the norms and compare it with the actual consumption. As a result, the amount of fuel savings or overconsumption will be determined.

Examples

Example 1. A ship with a steam-turbine power plant develops a speed of 20 mi/h (knots) with a GTZA power of 22,200 kW and a screw propeller revolution rate of 90 r/min, and consumes 5.75 t/h of fuel oil. Let us determine the travel time and fuel oil consumption for a voyage of 3,000 mi, as well as the travel time, GTZA power, screw propeller rate of revolution and fuel oil consumption for the same voyage at a speed of 15 mi/h.

Travel time for a voyage of 3,000 mi at a speed of 20 mi/h:

$$\frac{3000}{20}$$
 = 150 h.

Fuel oil consumption:

$$5,75 \cdot 150 = 862$$
 t.

Travel time for the same voyage at a speed of 15 mi/h:

$$\frac{3000}{15}$$
 = 200 h.

Required rate of screw propeller revolution:

$$90 \cdot \frac{15}{20} = 67.5 \text{ r/min.}$$

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GTZA power:

$$22\,200\left(\frac{15}{20}\right)^3 - 9368 \text{ kW}.$$

Hourly fuel oil consumption:

$$5,75 \frac{9368}{22200} = 2,43$$
 t.

Fuel consumption for the entire voyage:

$$2.43 \cdot 200 = 486$$
 t.

Example 2. A steamship with a 6,660-kW main engine consumes 1.45 t/h of motor fuel at full engine power and develops a speed of 16 mi/h. For an upcoming voyage of 8,000 mi the steamship has a fuel reserve of 730 t (not counting the usual marine reserve of 10-15 percent). However, the first 3,000 mi are sailed under stormy weather conditions that led to the additional consumption of 100 t of fuel. At what speed and what main engine power must the steamship cover the remaining 5,000 mi in order for the remaining fuel to be sufficient for the voyage?

Since the steamship uses 1.45 t/h at a speed of 16 mi/h, for the voyage of 3,000 mi it took 3,000/16 = 187.5 h and, under normal conditions $1.45 \cdot 187.5 = 272$ t of fuel would have been consumed. Because of the storm the actual fuel consumption was 272 + 100 = 372 t. There remains 358 t of fuel

In order to cover the remaining 5,000 mi at the previous speed, it would take 5,000/16 = 312 h and $1.45 \cdot 312 = 453$ t of fuel.

According to formula (103), fuel consumption on a voyage is proportional to the squares of the speeds:

$$\frac{G_1}{G_2} = \frac{v_1^2}{v_2^2} \; .$$

In this case, at a speed of 16 mi/h the fuel consumed for a voyage of 5,000 mi is 453 t. It is necessary to find the speed at which the fuel consumed will be 358 t:

$$\frac{358}{453} = \frac{v^2}{16^2}$$

from which the unknown speed is

$$v = \sqrt{\frac{16^2 \cdot 358}{453}} = 16 \sqrt{\frac{358}{453}} = 14.25 \text{ mi/h}.$$

The duration of the voyage will be

$$\frac{5000}{14.25} = 351 \text{ h}.$$

According to formula (102), hourly fuel consumption at a speed of 14.25 mi/h is

$$B = 1.45 \left(\frac{14.25}{16}\right)^3 = 1.02$$
 t/h.

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In this mode, the main engine's power can be assumed to be proportional to the fuel consumption:

$$N = 6660 \frac{1.02}{1.45} = 4680 \text{ kW}.$$

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CSO: 8144/1883

NAVIGATION AND GUIDANCE SYSTEMS

UDC 531.383(075)

GYROSTABILIZERS FOR INERTIAL GUIDANCE SYSTEMS

Leningrad GIROSTABILIZATORY INERTSIAL'NYKH SISTEM UPRAVLENIYA in Russian 1979 (signed to press 19 Feb 79) pp 2-4, 149-150

[Annotation, preface and table of contents from book "Gyrostabilizers for Inertial Guidance Systems", by Leonid Anatol'yevich Severov, Izdatel'stvo Leningradskogo universiteta, 924 copies, 152 pages]

[Text] The book considers gyroscopic stabilizers of uncorrected inertial guidance systems for unmanned flight vehicles. Principal attention is given to problems of analyzing and synthesizing the platform stabilization loop. A kinematic and dynamic description is given of gyrostabilizers with various designs of Cardan suspensions of the platform, different arrangements of gyroscopes and stabilizing motors. The problem of analytical construction of practically realizable optimum regulators for gyrostabilizers is formulated and solved. The possibility of realizing large gains in the stabilization loop is analyzed both from the standpoint of structural conditions of stability of a linear multidimensional system, and from the condition of absolute stability of a system with typical nonlinear elements.

The book is intended for specialists dealing with the design of gyrostabilizers, and may also be of use to undergraduate and graduate students in the appropriate fields.

Reviewers: Honored Worker in Science and Technology of the RSFSR, Doctor of Physical and Mathematical Sciences, Professor N. V. Butenin (Military Engineering Institute imeni A. F. Mozhayskiy), Doctor of Technical Sciences, Professor Ye.L. Smirnov (Leningrad Higher Engineering Naval Academy imeni Admiral S. O. Makarov).

Figures 35, references 80.

Preface

Modern self-contained inertial guidance systems of flightcraft are constructed with gyroscopic stabilization of the inertial sensing elements, most frequently implemented by a triaxial gyroscopic stabilizer [Ref. 1-5].

As a rule, inertial guidance systems use inertial orientation of the triaxial gyroscopic stabilizer. The short working time of the system enables construction of

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inertial guidance systems of open type [Ref. 6]. In more exact solution of the control problem, consideration is taken of variation in components of the acceleration due to gravity during flight [Ref. 1]. What has been said implies that the error of inertial guidance systems will include errors introduced by the triaxial gyroscopic stabilizer. Therefore in designing the triaxial gyroscopic stabilizer particular attention is given to the solution of two major problems: 1) precision initial deployment of the platform with inertial sensing elements; 2) assurance of exact inertial orientation of the platform during flight.

It should be noted that triaxial gyroscopic stabilizers of the given type operate during flight under conditions of intense vibrations and g-forces. This appreciably complicates solution of the second major problem and requires construction of a platform stabilization loop with large amplification factors, and adoption of special measures to reduce instrumental drifts of the platform [Ref. 4].

This monograph deals mainly with problems of analyzing and designing the platform stabilization system. A mathematical model of a multidimensional stabilization system is developed that accounts for elastic deformations of elements, typical nonlinearities, and a variety of configurations of gyroscopes and stabilizing motors. An analysis is made of the makeup of perturbing factors, and the problem of analytical construction of practically realizable optimum regulators for the triaxial gyroscopic stabilizers of inertial guidance systems is formulated and solved. The possibility of realizing large coefficients of amplification in the stabilization system is analyzed both from the standpoint of structural conditions of stability of the triaxial gyroscopic stabilizers designed around two-degree gyroscopes and from conditions of absolute stability of a nonlinear multidimensional system that contains typical nonlinearities of the components.

It is the author's hope that this book will be of use in the solution of problems of designing triaxial gyroscopic stabilizers of inertial guidance systems.

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UDC 531.3:62-50;519.9

MOTION STABILITY, ANALYTICAL MECHANICS, MOTION CONTROL

Moscow USTOYCHIVOST' DVIZHENIYA, ANALITICHESKAYA MEKHANIKA, UPRAVLENIYE DVIZHENIYEM in Russian 1981 (signed to press 6 Mar 81) pp 2, 302-304

[Annotation and abstracts of articles from book "Motion Stability, Analytical Mechanics, Motion Control", edited by Associate Member of USSR Academy of Sciences V. M. Matrosov and Doctor of Physical and Mathematical Sciences V. G. Demin, Siberian Power Engineering Institute, Siberian Department, USSR Academy of Sciences, Izdatel'stvo "Nauka", 1200 copies, 304 pages]

[Text] The collection is devoted to the theory of motion stability and its applications, as well as analytical mechanics and motion control.

It includes materials of plenary and sectional reports of the most eminent Soviet specialists in these fields delivered at the Third All-Union Chetayev Conference on Motion Stability, Analytical Mechanics and Motion Control in Irkutsk.

The collection is intended for scientific workers in the field of mechanics, mathematics and control theory, engineers, graduate students and upperclassmen.

UDC 519.011

DEVELOPMENT OF OPTICAL-MECHANICAL ANALOGY IN WORKS BY N. G. CHETAYEV

[Abstract of article by Rumyantsev, V. V.]

[Text] A historical survey of development of optical-mechanical analogy is given, and research by N. G. Chetayev on this problem is presented. References 7.

UDC 519.9

OPTIMUM CONTROL OF GROUPS OF TRAJECTORIES

[Abstract of article by Anan'ina, T. F., Kurzhanskiy, A. B. and Nikonov, O. N.]

[Text] It is assumed that the initial data and some of the controls of the system are undefined; optimization is carried out with respect to a functional that is assigned on the group of trajectories. Conditions of optimality are given for some problems. References 24.

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UDC 519.5

BIPEDAL WALKING: MODEL PROBLEMS OF DYNAMICS AND CONTROL

[Abstract of article by Beletskiy, V. V.]

[Text] The paper reviews some late research on this problem. An examination is made of questions of motion optimization and stabilization, in particular for underwater walking and three-dimensional maneuvering. Table 1, figures 4, references 16.

UDC 531.3

EXTREMUM PROPERTIES OF RESONANT MOTIONS

[Abstract of article by Beletskiy, V. V.]

[Text] The author formulates a hypothesis of maximality of an averaged force function on stable periodic motions. He discusses the relation between this principle and the extremum criteria of Blekhman and Poincaré, as well as the Owenden principle. Tables 2, figures 5, references 19.

UDC 531.3

STABILITY OF ORBITAL SYSTEMS

[Abstract of article by Blekhman, I. I.]

[Text] The author formulates an integral criterion of stability of synchronous (resonant) motions. Application of this criterion to a system of generalized vibration exciters and problems of celestial mechanics is considered. Figures 5, references 18.

UDC 531.394

METHODS OF GROUP THEORY FOR CONTINUOUS TRANSFORMATIONS IN MECHANICS OF SYSTEMS WITH FINITE NUMBER OF DEGREES OF FREEDOM

[Abstract of article by Bogoyavlenskiy, A. A., Yemel'yanova, I. S., Markhashov, L. M., Pavlovskiy, Yu. N. and Yakovenko, G. N.]

[Text] Survey on application of group theory methods for continuous transformations to problems of general mechanics and motion control theory. References 263.

UDC 531.3

NORMAL FORM AND THE METHOD OF AVERAGING

[Abstract of article by Bryuno, A. D.]

[Text] The author discusses the relation between classical methods of averaging and the reduction of an analytical system to normal form in the vicinity of a stationary point and an invariant manifold. References 17.

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UDC 531.011

CONDITIONS OF ABSOLUTE MINIMALITY IN THE PRINCIPLE OF LEAST ACTION

[Abstract of article by Velichenko, V. V.]

[Text] The set of examined detours is narrowed in accordance with the proposed concept of the region of attainability. The direct route confers an absolute minimum on the action. Figures 2, references 10.

UDC 531.38

DYNAMICS OF GYROSCOPE SYSTEM

[Abstract of article by Yegarmin, N. Ye., Zhbanov, Yu. K., Klimov, D. M. and Stepanenko, N. P.]

[Text] A frame of gyrocompass type is used to stabilize a massive solid. Free motion of the system is considered, as well as motion in a circular orbit in a newtonian force field. The process of transition to the stable steady state is considered. Figures 3, references 5.

UDC 531.38

SIMPLEST MOTIONS OF MECHANICAL SYSTEMS AND THEIR STABILITY

[Abstract of article by Irtegov, V. D.]

[Text] A method is pointed out for isolating integral manifolds of differential equations and their Lyapunov stability is studied. References 11.

UDC 531.38

STEADY-STATE MOTIONS OF A HEAVY SOLID WITH DYNAMIC SYMMETRY SUSPENDED ON A STRING

[Abstract of article by Ishlinskiy, A. Yu., Malashenko, S. V., Storozhenko, V. A. Temchenko, M. Ye. and Shishkin, P. G.]

[Text] Motion of a solid in a string drive is considered for substantiating a method of rotor balancing. There are four families of steady-state motions. Their bifurcations are studied. Research on experimental verification of the balancing idea is described. Figures 6, references 14.

UDC 519.9

PROBLEMS OF CONTROLLING SYSTEMS WITH ELASTIC LAG

[Abstract of article by Kirillova, F. I., Gabasov, R., Zabello, L. Ye. and Marchen-ko, V. M.]

[Text] Problems of relative, pointwise, complete and modal controllability, spectral finiteness and point degeneracy are studied for linear systems with delay. References 37.

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UDC 531.3

MISSING RESTRICTED SOLUTION PRINCIPLE IN ABSOLUTE STABILITY PROBLEM

[Abstract of article by Krasnosel'skiy, M. A. and Pokrovskiy, A. V.]

[Text] Theorems are presented on absolute stability relative to differential systems based on the principle of absence of restricted solutions as $t \to \infty$. Abolute stability of multiply connected automatic control systems is considered as an application. Figures 2, references 11.

UDC 519.9

SINGULAR PERTURBATIONS IN OPTIMUM CONTROL PROBLEMS

[Abstract of article by Kreyn, S. G. and Kurina, G. A.]

[Text] The Mayer problem and the classical minimization problem are studied for a perturbed system of the type $(A+\epsilon B)\dot{x}(t)=Cx(t)+Du(t)$, where A, B, C, D are constant matrices, A being degenerate, and ϵ is a small parameter. References 13.

UDC 531.3

RESONANT PROBLEMS IN MOTION STABILITY THEORY

[Abstract of article by Kunitsyn, A. L. and Markeyev, A. P.]

[Text] A survey of results and methods of studying stability of resonant systems, both hamiltonian and nonhamiltonian. References 44.

UDC 521.1

TRAJECTORIES OF THE PLANAR RESTRICTED THREE-BODY PROBLEM THAT ARE BIASYMPTOTIC TO COLLINEAR LIBRATION POINTS

[Abstract of article by Didov, M. L. and Vashkov'yak, M. A.]

[Text] Numerical methods are used to construct some of the mentioned trajectories for the circular problem. Two of them are used as generating solutions for constructing families of the corresponding trajectories of the elliptical problem. Table 1, figures 6, references 6.

UDC 62-50:517.917

COMPARISON PRINCIPLE IN DYNAMICS OF DISTRIBUTED-PARAMETER SYSTEMS

[Abstract of article by Matrosov, V. M. and Vasil'yev, S. N.]

[Text] The authors use comparison vector functions that satisfy Chaplygin differential inequalities, and also differential comparison systems. A standardized

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representation is proposed for definitions of dynamic properties of systems and the comparison principle in dynamics of controllable systems by using quantor formulas of mathematical logic. Algorithms of formulations and proofs are defined and computerized for comparison theorems from the given formulas. Figures 2, references 13.

UDC 517.934

INVERSE PROBLEMS OF DYNAMICS

[Abstract of article by Mukharlyamov, R. G.]

[Text] Methods are presented for solving these problems: direct construction of differential motion equations with predetermined program properties, and methods based on using principles of possible displacements and least constraint. References 14.

UDC 519.5

DEVELOPMENT OF AN INTEGRATED WALKING ROBOT

[Abstract of article by Okhotsimskiy, D. Ye., Platonov, A. K., Gurfinkel', V. S. and Devyanin, Ye. A.]

[Text] Basic principles are outlined for organizing operation of an integrated robot. An examination is made of problems of synthesizing motion of a walking machine. Stages of mathematical modeling of the motion and development of laboratory models are described. Figures 16, references 30.

UDC 62-50:519.9

SOME PROBLEMS OF STABILITY AND STABILIZATION IN DIFFERENTIAL GAMES

[Abstract of article by Reshetov, V. V., Subbotin, A. I. and Ushakov, V. N.]

[Text] An examination is made of the use of guided control in various problems. An improved procedure is described that is suitable for a process taken on an infinite half-interval of time. References 12.

UDC 531.38

STABILITY OF STEADY-STATE ROTATIONS OF A FREE SOLID WITH ELASTIC CYLINDRICAL SHELL CONTAINING A LIQUID AS THE SYSTEM MOVES BY INERTIA

[Abstract of article by Rubanovskiy, V. N.]

[Text] Sufficient stability conditions are derived in explicit form for uniform rotations of a free cylindrical shell with a sloshing liquid. References 5.

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UDC 531.38

SIGNIFICANCE OF GEOMETRIC METHODS IN PROBLEMS OF SOLID-STATE DYNAMICS

[Abstract of article by Kharlamov, P. V.]

[Text] An examination is made of problems involving geometric representation of motion. The hodograph method is presented. Examples refer to the Poinsot interpretation and the Lagrange solution. Figures 9, references 26.

UDC 519.9

OPTIMUM MOTION CONTROL PROBLEM FOR THE CASE WHERE CONTROL IS A FUNCTION OF A PREDETERMINED OUTCOME OF THE SYSTEM

[Abstract of article by Yakubovich, V. A.]

[Text] A necessary optimality condition analogous to Pontryagin's "maximum principle" is proved. Figure 1, references 7.

UDC 531.38

ROTATION-STABILIZED SATELLITES

[Abstract of article by Sarychev, V. A., Sazonov, V. V. and Mirer, S. A.]

[Text] A damping device in the form of a two-degree gyroscope is considered for ensuring constant orientation of the axis of the maximum moment of inertia in an inertial frame of reference. Damping is by forces of viscous friction as the gyroscope moves relative to the body of the satellite. Figures 2, references 9.

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FLUID MECHANICS

UDC 533.6.013.42

ELASTIC SHELL PENETRATION INTO COMPRESSIBLE LIQUID

Kiev PRONIKANIYE UPRUGIKH OBOLOCHEK V SZHIMAYEMUYU ZHIDKOST' in Russian 1981 (signed to press 12 Dec 80) pp 2, 160

[Annotation and table of contents from book "Elastic Shell Penetration Into Compressible Liquid", by V. D. Kubenko, Institute of Mechanics, UkSSR Academy of Sciences, Izdatel'stvo "Naukova dumka", 161 pages]

[Text] The monograph investigates hydrodynamic loads and the stress-strain state that arises in solids and elastic shells upon striking a liquid surface. Higher penetration velocities can be considered by accounting for compressibility of the liquid. The analysis covers the early stage of penetration during which hydrodynamic loads on the penetrating body reach a maximum. Approaches are given for determining hydrodynamic pressure upon penetration of bodies of fairly general configuration. The stressed and strained state of penetrating elastic shells is determined. Some specific results are given.

For scientists, engineers and technicians working in design of structural components for impact action.

Figures 62, references 39.

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MECHANICS OF SOLIDS

UDC 539.377

GENERALIZED FUNCTIONS IN THERMOELASTICITY (COLLECTION OF SCIENTIFIC PAPERS)

Kiev OBOBSHCHENNYYE FUNKTSII V TERMOUPRUGOSTI (SBORNIK NAUCHNYKH TRUDOV) in Russian 1980 (signed to press 9 Dec 80) pp 2, 209-216

[Annotation and abstracts of articles from book "Generalized Functions in Thermoelasticity (Collection of Sciencific Papers)", Institute of Applied Problems of Mechanics and Mathematics, UkSSR Academy of Sciences, Izdatel'stvo "Naukova dumka", 950 copies, 216 pages]

[Text] The collection deals with questions of using generalized functions in problems of thermal conductivity, thermoelasticity and magnetothermoelasticity of piecewise homogeneous solids, rods, plates and shells with stepwise changes in cross section and thickness, solids with cracks, welded structural components and other problems that arise in electronics, instrument making and other fields of industry.

The collection is intended for scientists, engineers and technicians, graduate students and upperclassmen in colleges and universities who are interested in problems of the thermophysics and thermomechanics of deformable solids.

UDC 539.377

THERMOELASTICITY OF INHOMOGENEOUS AND PIECEWISE-HOMOGENEOUS PLATES THAT HAVE CYLIN-DRICAL ANISOTROPY

[Abstract of article by Kolyano, Yu. M. and Protsyuk, B. V.]

[Text] Equations of the dynamic problem of thermoelasticity are derived for inhomogeneous and piecewise-homogeneous plates that have cylindrical anisotropy, based on a linear law of temperature distribution with respect to the thickness of the plate and the Kirchhoff-Love hypothesis. References 5.

UDC 539.377

EQUATIONS OF THERMAL CONDUCTIVITY AND THERMOELASTICITY OF INHOMOGENEOUS AND PIECE-WISE-HOMOGENEOUS PLATES WITH RECTILINEAR ANISOTROPY

[Abstract of article by Kolyano, Yu. M. and Kushnir, R. M.]

[Text] Equations of thermal conductivity and the dynamic problem of thermoelasticity are derived for inhomogeneous plates that have rectilinear anisotropy, and these

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expressions are then used as a basis for getting the corresponding equations of laminar plates. The corresponding equations for composite plates are also found on the basis of the equations of homogeneous plates and conditions of ideal thermomechanical contact. As an example, the problem of heat conduction is considered for joined infinite heterogeneous orthotropic plates heated by a linear source of heat. References 12.

UDC 539.377

TEMPERATURE FIELDS THAT ARISE DURING FRICTION MARDENING OF FLAT PIECES

[Abstract of article by Babey, Yu. I., Didyk, V. Z., Korduba, B. M. and Maksimishin, M. D.]

[Text] The quasi-steady temperature field is determined in a semi-infinite plate with heat flux moving at constant velocity in a narrow zone along the edge. Temperature fields are studied in steel and cast iron plates. Figures 3, references 4.

UDC 536.12

SOLUTION OF THE ONE-DIMENSIONAL HEAT CONDUCTION PROBLEM WITH PREDETERMINED MEAN INTEGRAL TEMPERATURE WITH RESPECT TO COORDINATE

[Abstract of article by Vigak, V. M. and Kostenko, A. V.]

[Text] The solution of the problem of thermal conductivity for a plate at a predetermined mean integral temperature is considered as applied to problems of speed-optimum control of heating of a body. It is shown that when the appropriate condition of matching between initial and boundary conditions is applied, there is a classical solution, and in the absence of this condition, the solution at time zero is a Dirac delta function.

UDC 539.377

TWO-DIMENSIONAL TEMPERATURE STRESSES IN PIECEWISE-HOMOGENEOUS LAYER RESULTING FROM ONE-DIMENSIONAL TEMPERATURE FIELD

[Abstract of article by Popovich, V. S., Malkiyel', B. S. and Lisak, R. S.]

[Text] Methods of Fourier-Laplace integral transforms and the apparatus of general-ized functions are used to solve the quasistatic problem of thermoelasticity for a layer with coordinate-dependent temperature coefficient of linear expansion in the case of unilateral heating by a medium with time-variable temperature. The resultant solution is used to study the temperature stresses in the glass-pyroceram cement joint of a color kinescope as a function of the thickness of the pyroceram cement. Figures 5, references 3.

UDC 539.377

DETERMINING OPTIMUM HEATING ZONES IN LOCAL HARDENING OF THIN-WALLED COMPONENTS [Abstract of article by Plyatsko, G. V., Maksimovich, V. N. and Chabanenko, A. A.] [Text] An examination is made of the problem of determining optimum heating zones such that residual stresses will be induced that have the experimental values in

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given regions. Constraints on plastic deformations are assumed in the heating zone. A detailed examination is made of plates with an elliptical hole and with a crack. Results of numerical calculations are given in graphs. Figures 3, references 9.

UDC 539.377

TEMPERATURE STRESSES IN PLATE WITH DISSIMILAR HEAT-RELEASING ELEMENT

[Abstract of article by Kulik, A. N. and Prikhodskaya, Ye. I.]

[Text] Assuming that the coefficient of heat transfer from the upper and lower circular surfaces of a straight-through cylindrical heat-releasing inclusion is constant, but different from the constant coefficients of heat transfer from the remainder of the upper and lower surfaces of an infinite plate, the authors determine and study the steady stressed state of the plate as a function of heat transfer, coefficients of heat conduction, temperature coefficients of linear expansion and elastic moduli. Figure 1, references 2.

UDC 539.4

DETERMINING OPTIMUM PARAMETERS OF LONGITUDINAL CROSS SECTIONS IN CLOSED CYLINDRICAL DAMPER SHELLS

[Abstract of article by Osadchuk, V. A.]

[Text] A method is proposed for determining the optimum dimensions and number of slits in a closed cylindrical damper shell. The relations used as a basis for determining optimum parameters are obtained by an energy approach, using an expression for the energy flow to the vertex of a cross section as normalized to a unit of area of the cross section. References 7.

UDC 536.12-539.376

TEMPERATURE FIELD OF A LAYER UPON THERMAL ACTION OF AN EXTERNAL MEDIUM ON A RECTANGULAR REGION OF ITS SURFACE

[Abstract of article by Grits'ko, Ye. G.]

[Text] A method is proposed for determining the temperature field of a layer under thermal action of an external medium on a finite region of its surface having two mutually perpendicular axes of symmetry. The technique is based on representing the unknown temperature field in the region of thermal action as a sum of functions that form an orthogonal system. A method is given for estimating accuracy of the results. References 3.

UDC 539.3

AXISYMMETRIC STRESSED STATE OF CYLINDERS THAT ARE NONUNIFORMLY HEATED AND LOADED ON A BOUNDARY SURFACE

[Abstract of article by Maksimovich, V. N.]

[Text] The author considers the problem of determining the stressed state of elastic cylinders under conditions of nonuniform heating and loaded on a boundary. The

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principal results of the work are found by applying the Varshchenko-Zakharchenko expansion formula to the symbolic solution. The resultant formulas can be used in calculating the stressed state of both infinite and bounded cylinders. References 4.

UDC 518:517.944/947

SOLUTION OF UNSTEADY PROBLEM OF HEAT CONDUCTION FOR A SPACE WITH SLITS BY THE INTEGRAL EQUATION METHOD

[Abstract of article by Berezhanskaya, Z. S., Lyudkevich, I. V. and Shinkarenko, G. A.]

[Text] A technique is proposed for calculating a temperature field in a space for multiply connected regions. The solution is sought in the form of a thermal potential of a simple layer by reducing it to an integral equation of the first kind that is solved by the method of collocation. The method used for approximating density gave a stable solution at large time values. The approximate solution of the formulated problem in contrast to net-point methods is found in analytical form. A numerical example is given of calculation of a temperature field. Figures 2, references 5.

UDC 539.377

STRESSES IN SEMI-INFINITE PLATE COVERED ON TWO SIDES EXPOSED TO EQUIDISTANT HEAT SOURCES

[Abstract of article by Kushnir, R. M.]

[Text] The paper gives the solution of a quasistatic proble of thermoelasticity for a thin semi-infinite plate with bilateral covering when heated by a system of equidistant lumped heat sources. Temperature stresses are studied in a steel semi-infinite plate with molybdenum coating on both sides. Figures 4, references 3.

UDC 539.377

STRESSES IN A STRIP PLATE CAUSED BY LOCALIZED HEATING

[Abstract of article by Gladunskiy, V. N.]

[Text] The author determines the temperature field and resultant temperature stresses in a thin strip plate exposed to heat sources distributed through the volume of the parallelepiped of such a plate with length coincident with the width and thickness coincident with the thickness of a strip of the plate. The coefficient of heat transfer from surfaces of the volume occupied by the heat sources is taken as constant and different from the constant coefficient of heat transfer from the remaining parts of the lateral surfaces of the strip of the plate.

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UDC 539.377

GENERALIZED HEAT CONDUCTION OF PLATES WITH TIME-VARIABLE THICKNESS

[Abstract of article by Pushak, Ya. S.]

[Text] Equations are derived for the generalized thermal conductivity of anisotropic plates of time-variable thickness. The temperature field is determined for an infinite plate heated by an external medium and having thickness that varies stepwise in time. References 3.

UDC 539.377

GENERALIZED DYNAMIC PROBLEM OF MAGNETOTHERMOELASTICITY FOR A LAYER SUBJECTED TO BILATERAL MAGNETIC IMPACT

[Abstract of article by Kondratyuk, N. A.]

[Text] Laplace trnasformation is used to solve the generalized dynamic problem of thermoelasticity for a heat-insulated layer that is free of external loading and is subjected to bilateral magnetic shock. References 5.

UDC 536.12-539.376

NARROW-ZONE HEATING OF ANISOTROPIC LAYER

[Abstract of article by Koval'chuk, V. P.]

[Text] The temperature field of an anisotropic layer is determined and studied for the case of a piecewise-constant coefficient of heat exchange from its surfaces. Numerical calculations are done for a quartz layer, and the results are given as graphs. Figures 2, references 3.

UDC 539.377

TEMPERATURE STRESSES IN ORTHOTROPIC SEMI-INFINITE PLATE CAUSED BY LOCAL HEATING

[Abstract of article by Litvinova, A. F.]

[Text] The author determines the temperature field and the temperature stresses for an orthotropic semi-infinite plate due to bilateral narrow-zone heating by an external medium along a strip perpendicular to the edge surface. A study is done on the influence that variability of the heat-transfer coefficient has on the distribution of unsteady temperature stresses on the edge of the plate. Figures 4, references 3.

UDC 539.377

GENERALIZED DYNAMIC THERMOELASTICITY PROBLEM FOR RADIANTLY HEATED HALF-SPACE

[Abstract of article by Semerak, F. V. and Borisenko, O. I.]

[Text] Generalized dynamic temperature stresses are determined in explicit form in a half-space heated by radiant energy flux in accordance with Bouguer law, the flux intensity being a function of time. References 2.

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UDC 539.376

CREEP OF A SOLID WITH LOAD RELIEF

[Abstract of article by Ivasyuk, V. V.]

[Text] Within the framework of the slip concept the author finds the analytical dependence of creep deformation under stress lower than the cold hardening stress. The solution is found in closed form in the class of generalized functions. References 6.

UDC 539.3:538.6

TEMPERATURE FIELDS AND STRESSES IN ELECTRICALLY CONDUCTIVE LAYER WITH INDUCTION HEATING IN AN EXTERNAL MAGNETIC FIELD

[Abstract of article by Kondrat, V. F. and Lopushanskiy, Ya. I.]

[Text] On the basis of an approximate solution of the problem of magnetothermoelasticity for an electrically conductive layer with induction heating in an external constant magnetic field, the authors investigate temperature fields and stresses in a layer as a function of the parameters of external action. Figures 2, references 4.

UDC 539.377

TEMPERATURE FIELD AND STRESSES IN A STRIP PLATE CAUSED BY A PLANAR HEAT SOURCE WITH ACCOMPANYING PREHEATING AND COOLING

[Abstract of article by Yaritskaya, L. I.]

[Text] Integral Fourier-Laplace transforms are used to solve the quasistatic problem of thermoelasticity for a thin strip plate heated by a planar heat source with accompanying preheating and cooling. References 3.

UDC 539.377

TEMPERATURE FIELD AND STRESSES THAT ARISE IN A DIE DURING PRESSING OF GLASS ITEMS

[Abstract of article by Semerak, M. M. and Yurchenko, P. Ye.]

[Text] A solution is given for the problem of determining the temperature field and stresses in a die caused by sudden heating of its surface. The process of molding a glass droplet is modeled by a stepwise increase in the radius of the circular contact area, using asymmetric unitary functions. The temperature fields and stresses in the die are studied. Figures 4, references 2.

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UDC 539.377

QUASISTATIC PROBLEM OF THERMOELASTICITY FOR MULTISTEP PLATE

[Abstract of article by Pushk, Ya. S.]

[Text] An examination is made of the quasistatic axisymmetric problem of thermoelasticity for a multistep circular plate heated by a source of heat. The solution of such a problem for a two-step plate is given as an example. References 2.

UDC 539.377

GENERALIZED DYNAMIC PROBLEM OF THERMOELASTICITY FOR SEMI-INFINITE PLATE WITH INCLUSION

[Abstract of article by Borisenko, O. I.]

[Text] Equations are derived for heat conduction of piecewise-homogeneous bodies, and the generalized problem of thermoelasticity of a half-space with an inclusion is considered as an example. An investigation is made of the influence that the thickness of the inclusion has on the distribtuion of generalized dynamic stresses in a plate. Figures 2, references 3.

UDC 539.377

TEMPERATURE FIELD AND STRESSES IN HEAT EXCHANGER HOUSING

[Abstract of article by Gudyma, Kh. N.]

[Text] The author considers a cylindrical shell with one of the lateral surfaces cooled with respect to a linear law in time, while the other is subjected to cooling by a medium moving over a helical surface. Integral Fourier and Laplace transforms are used to determine the temperature field, and analytical expressions are found for the stresses caused by temperature gradients. References 2.

UDC 536.2:517.534:518.5

TEMPERATURE FIELDS IN A HALF-SPACE WITH LAMINAR INCLUSION

[Abstract of article by Romanchuk, O. K.]

[Text] The temperature field is determined and studied in a half-space with a dissimilar inclusion in the form of a thin plate for the case of harmonic thermal action. As a result of representing the thermophysical characteristics of the system in the form of asymmetric unitary functions and solving the corresponding problem, the author gets a unified analytical solution for the entire investigated region. A study is done on the distribution of the unsteady temperature field in the half-space as a function of time, frequency and coordinate. Figures 4, references 3.

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UDC 539.377

QUASISTATIC TEMPERATURE STRESSES IN STRIP PLATE CAUSED BY A HEAT SOURCE MOVING PERPENDICULAR TO ITS ENDS

[Abstract of article by Kalyniy, Ya. N.]

[Text] The author determines the unsteady temperature field and quasistatic temperature stresses in a strip plate heated by a source moving perpendicular to its ends. As a special case, the temperature field is found in a semi-infinite plate heated by a linear heat source moving perpendicular to the edge of the plate. References 5.

UDC 539.377

UNSTEADY TEMPERATURE STRESSES IN MULTILAYER CIRCULAR PLATE DUE TO HEAT FLOW

[Abstract of article by Kolesov, V. S., Protsyuk, B. V. and Vlasov, N. M.]

[Text] The authors determine unsteady temperature fields and the corresponding temperature stresses in a multilayer circular plate caused by heating by a heat flux that varies in accordance with Gauss law. The temperature field in a five-layer plate is studied. References 2.

UDC 539.377

EQUATIONS OF HEAT CONDUCTION OF PIECEWISE-HOMOGENEOUS ANISOTROPIC PLATES WITH CURVILINEAR INTERFACES

[Abstract of article by Protsyuk, B. V.]

[Text] An integral heat-balance method is used to derive equations of unsteady heat conduction of anisotropic piecewise-homogeneous plates with curvilinear interfaces. References 3.

UDC 539.377

THERMOELASTIC PROBLEM FOR SQUARE PLATE WITH TWO CIRCULAR OPENINGS

[Abstract of article by Lozinskiy, V. N.]

[Text] An examination is made of the static problem of thermoelasticity for a square plate that is free of external loading, heat-insulated along the lateral surfaces, weakened by two circular holes and subjected to the action of a linear heat source. Constant temperatures are assigned on the contours of the plate. Problems of thermal conductivity and thermoelasticity are reduced to solution of quasiregular systems of linear algebraic equations. References 6.

UDC 536.12

PLATE HEATING BY A CONICAL STATIONARY HEAT SOURCE

[Abstract of article by Khuda, O. Z. and Podkova, Ya. I.]

[Text] The authors determine the steady-state temperature field of a thin plate heated by a stationary source in the form of a frustum of a cone. An investigation is made of the influence that the vertex angle of the cone, heat transfer, and the distance of the vertex of the cone from one of the surfaces of the plate have on the temperature field. Figures 4.

UDC 539.3

USING THE METHOD OF INTEGRAL CHARACTERISTICS IN HEAT CONDUCTION OF ANISOTROPIC PLATES WITH PIECEWISE-CONSTANT HEAT TRANSFER COEFFICIENTS

[Abstract of article by Pryymak, V. I.]

[Text] The method of integral characteristics is used to determine the steady-state temperature field in an infinite plate that has rectilinear anisotropy and is heated by an external medium over a rectangular region. A study is done on the temperature in the center of a plate made of KAST-V glass-textolite. Figure 1, references 3.

UDC 539.377

THERMAL STRESSES IN A SPHERICAL SHELL DUE TO A HEAT SOURCE IN THE FORM OF LINES

[Abstract of article by Khapko, B. S. and Zabolotnyy, V. P.]

[Text] A solution of the problem of thermoelasticity is given for a thin shallow spherical shell of circular planform under the action of a momentary heat source in the form of a line. The shell, with contour taken as freely supported, exchanges heat with the ambient medium in accordance with Newton's law. Sources in the form of an arc and a line along the radius are considered as examples. References 3.

UDC 621.385.832

CALCULATING REFLECTIVITY DISTRIBUTION ON INNER FACE OF APERTURE-MASK COLOR PICTURE TUBE SCREEN

[Abstract of article by Malkiyel', B. S. and Rykhlinskaya, S. I.]

[Text] A method is proposed for calculating the distribution of reflectivity of the inner surface of the screen of a shadow-mask color kinescope that is used to balance the temperature over the surface of the shadow mask immediately after the television set is switched on. Such a distribution of reflectivity can eliminate warping of the mask toward the screen in the middle, and the related displacement of electron-beam traces relative to the phosphor dots. Surfaces of the middle part of the screen and mask are given properties of absorption, while the edges are given properties of reflection. Figures 4, references 3.

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UDC 517+519+532+533+62

DYNAMICS AND STABILITY OF MECHANICAL SYSTEMS

Kiev DINAMIKA I USTOYCHIVOST' MEKHANICHESKIKH SISTEM (SBORNIK NAUCHNYKH TRUDOV) in Russian 1980 (signed to press 12 Aug 80) pp 2, 192-193

[Annotation and table of contents from book "Dynamics and Stability of Mechanical Systems (Collection of Scientific Articles)", edited by Doctor of Physical and Mathematical Sciences I. A. Lukovskiy, Institute of Mechanics, UkSSR Academy of Sciences, 1000 copies, 194 pages]

[Text] The collection offers articles on the dynamics of solid and deformable bodies with inner cavity containing a sloshing liquid; on development of algorithms for Lyapunov's second method, and also the Routh-Hurwitz matrix problem in the theory of motion stability as applied to multidimensional systems; some articles reflect the investigation of instrumental errors of inertial guidance systems and their stability.

Intended for scientists, engineers and graduate students specializing in the corresponding fields of mechanics and control.

page Contents Lukovskiy, I. A., "Using variational principle of Ostrogradskiy type in solving nonlinear problems of solid-state dynamics for a body with cavities contain-3 ing liquid" Pil'kevich, A. M., "Constructing approximate solutions of nonlinear liquid 16 wave motion equations in vessel" Barnyak, M. Ya., "Determining natural oscillation frequencies and modes for 22 viscous liquid in horizontal channel" Lukovskiy, I. A., Zolotenko, G. F., 'Motion theory for solid with cavities containing liquid and oscillating mass of pendulum type" 30 Komarenko, A. N., Shvets, G. A., "Determining hydrodynamic coefficients for motion equations of solid with oblique cylindrical cavity containing 50 liquid" Luneva, S. A., "Method of calculating variable-section waveguide with consideration of singularities at corner points" 64 Boriseyko, V. A., "Plane wave diffraction by circular disk" Temchenko, M. Ye., "Operational errors of single-component inertial guidance 69 74 system due to gyroscope drift and newtonmeter errors" Storozhenko, V. A., Korneyeva, A. S., "Instability study of spatial inertial 88 guidance system'

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